DOCUMENTS EXPEDITIL. PRO.ECT

86th Congress
1st Session

JOINT COMMITTEE PRINT

SELECTED MATERIALS ON EMPLOYEE RADIATION HAZARDS AND WORKMEN'S COMPENSATION

JOINT COMMITTEE ON ATOMIC ENERGY

CONGRESS OF THE UNITED STATES

FEBRUARY 1959

Printed for the use of the Joint Committee on Atomic Energy

UNITED STATES
GOVERNMENT PRINTING OFFICE
34434 WASHINGTON : 1959

JOINT COMMITTEE ON ATOMIC ENERGY

CLINTON P. ANDERSON, New Mexico, *Chairman*
CARL T. DURHAM, North Carolina, *Vice Chairman*

RICHARD B. RUSSELL, Georgia	CHET HOLIFIELD, California
JOHN O. PASTORE, Rhode Island	MELVIN PRICE, Illinois
ALBERT GORE, Tennessee	WAYNE N. ASPINALL, Colorado
HENRY M. JACKSON, Washington	ALBERT THOMAS, Texas
BOURKE B. HICKENLOOPER, Iowa	JAMES E. VAN ZANDT, Pennsylvania
HENRY DWORSHAK, Idaho	CRAIG HOSMER, California
GEORGE D. AIKEN, Vermont	WILLIAM H. BATES, Massachusetts
WALLACE F. BENNETT, Utah	JACK WESTLAND, Washington

JAMES T. RAMEY, *Executive Director*

SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT

MELVIN PRICE, Illinois, *Chairman*

CARL T. DURHAM, North Carolina	JOHN O. PASTORE, Rhode Island
JAMES E. VAN ZANDT, Pennsylvania	ALBERT GORE, Tennessee
CRAIG HOSMER, California	BOURKE B. HICKENLOOPER, Iowa

G. EDWIN BROWN, Jr., *Professional Staff Member*

LETTER OF TRANSMITTAL

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
U.S. Congress.

DEAR MR. CHAIRMAN: Transmitted herewith for the information of the Joint Committee, the Congress, and the public are selected materials on employee radiation hazards and workmen's compensation which will be the subject of public hearings next month by the Subcommittee on Research and Development. The subcommittee's hearings, which are scheduled to begin March 10 and extend through March 19, are aimed primarily at developing and compiling information on the many complex aspects of this problem as a guide for future action.

The materials in this print include a detailed report by the AEC, in cooperation with the Department of Labor and others, which covers the major subject areas involved and was prepared in response to my request of last May. The print also includes selected statements, articles, and other documents which are a representative sampling of informed opinion on various aspects of the problem. It is hoped that these materials, printed in advance of the hearings, will prove useful to committee members and all others interested in this important area of inquiry.

Sincerely yours,

MELVIN PRICE,
Chairman, Subcommittee on Research and Development.

CONTENTS

	Page
Letter of transmittal	III
Outline of hearings by Research and Development Subcommittee	VII
Chapter 1. Report to the Joint Committee by AEC entitled "Employee Radiation Hazards and Workmen's Compensation":	
Foreword	1
Part I. General Background	2
Part II. Standards, Administrative Requirements, and Protective Measures—AEC Contractor Activities	26
Part III. Industrial Experience—AEC Contractors	29
Part IV. Radiation protection in the AEC licensing program	48
Part V. Radiation protection training	60
Part VI. Radiation Exposure, Injury, and Compensation	69
Appendixes:	
Appendix A. The National Committee on Radiation Protection and Measurement—Its organization, membership, and accomplishments	101
Appendix B. AEC manual requirements	113
Appendix C. Current status of AEC licensing program	131
Appendix D. Views of two AEC consultants on radiation exposure and compensation	133
Appendix E. Supporting tables and other data to part VI, section 3 "Analysis of Workmen's Compensation Laws in Relation to Radiation Injuries"	141
Chapter 2. Associated Documents and Materials:	
Part I. Radiation Protection in the Industrial Use of Radiation—Paper by W. A. McAdams, General Electric Co., presented at Second Geneva Conference on Peaceful Uses of Atomic Energy	173
Part II. Workmen's Compensation and Radiation Hazards—Paper by Dr. Earl Cheit, St. Louis University, presented to AFL–CIO Conference on Atomic Radiation Hazards, Washington, D.C., February 27, 1957	179
Part III. What Protection Do Present Workmen's Compensation Laws Afford Workers and Their Families Against Wage Loss for Disability or Death From Occupational Diseases—Address by Ashley St. Clair, Liberty Mutual Insurance Co., presented to Annual Convention of Industrial Accident Boards and Commissions, Seattle, September 9, 1958	185
Part IV. Radiation and Workmen's Compensation—Address by A. J. Biemiller, Legislative Department, CIO–AFL Conference on Workmen's Compensation, April 15, 1958	206
Part V. Report on Workmen's Compensation, by the Special Committee on Atomic Energy Law, presented to Annual Meeting of the American Bar Association, 1957	210
Part VI. Extract from "Suggested State Legislation"—Program for 1959, prepared by Committee of State Officials on Suggested State Legislation, Council of State Governments	214
Part VII. Report by Council of State Governments on Workmen's Compensation Standards, including Suggested State Legislation, 1959	218
Part VIII. Report of Atomic Energy Committee, International Association of Industrial Accident Boards and Commissions, to 44th Annual Convention, Seattle, September 9, 1958	230
Part IX. AEC Regulation on Standards for Protection Against Radiation (Title 10—Atomic Energy, Chapter 1, Part 20)	238
Part X. Summary of accidents and incidents involving radioactive material in atomic energy activities, June 1945–December 1958	254

CONTENTS

Page

Letter of transmittal III

Outline of hearings by Research and Development Subcommittee VII

Chapter 1. Report to the Joint Committee by AEC critical "Employee Relations, Hazards and Workmen's Compensation":

Foreword 1

Part I. General Background 2

Part II. Standards, Administrative Requirements, and Procedures 26

Part III. Industrial Experience—AEC Contractors 29

Part IV. Relation proposals in the AEC licensing program 48

Part V. Relative responsibilities 60

Part VI. Relations, injury, and Compensation 69

Appendix A. The National Committee on Radiation Protection and Measurements, Maximum permissible amounts 101

Appendix B. 113

Appendix C. Chronology of AEC operations 121

Appendix D. Some of the AEC consultants on radiation exposure 132

Appendix E. 141

Chapter 2. Associated Documents and Statistics:

Part 1. Radiation Protection in the Industrial Use of Radiation—Report by W. A. Mills, General Electric Co., presented as Conference on Industrial Hygiene in Atomic Energy 173

Part II. Workmen's Compensation and Radiation Hazards—Paper by Jos. Zoss Chair, St. Louis University, presented to AFL–CIO Conference on Atomic Radiation Hazards, Washington, D.C., February 27, 1957 179

Part III. What Protection Do Present Workmen's Compensation Laws Afford Workers and Their Families Against Wage Loss for Disability or Death From Occupational Diseases—Address by Harry Jay Clark, Liberty Mutual Insurance Co., presented to Annual Conference of Industrial Accident Boards and Commissioners, October 6, 1955 183

Part IV. Radiation and Workmen's Compensation—Address by J. J. Keeling, Legislative Committee, CIO–AFL Conference on Workmen's Compensation, March 18, 1958 206

Part V. Report on Workmen's Compensation, by the Special Committee to Atomic Energy Law, presented to Annual Meeting of the American Bar Association, 1957 210

Part VI. Letters from Commercial Insurance Companies—Program for Legislation, Council of State Governments 214

Part VII. Reports by Council of State Governments on Workmen's Compensation Standards, Including Excerpted State Legislation, 1955 218

Part VIII. Report of Atomic Energy Commission Interdepartmental Association of Industrial Accident Boards and Commissions, to 44th Annual Convention, Seattle, September 9, 1958 230

Part IX. AEC Regulation on Standards for Protection Against Radiation (Title 10—Atomic Energy, Chapter 1, Part 20) 238

Part X. Summary of accidents and incidents involving radioactive material in atomic energy activities, June 1945–December 1958 254

FEBRUARY 10, 1959.

JOINT COMMITTEE ON ATOMIC ENERGY

SUBCOMMITTEE ON RESEARCH AND DEVELOPMENT

PUBLIC HEARINGS ON EMPLOYEE RADIATION HAZARDS AND WORKMEN'S COMPENSATION

March 10, 11, 12, 17, 18, 19, 1959

OUTLINE

Tuesday, March 10 (P.M.)

I. GENERAL BACKGROUND. Background statement outlining the broad problem of industrial radiation hazards as a general framework for subsequent detailed discussion of radiation hazards to employees in atomic energy installations, including:

- A. Opening Statement.
- B. Standards and Their Historical Development.
- C. Origin and Nature of Industrial Hazards and Radiation Injuries:
  1. Source of injury.
  2. Kinds of injury.
  3. General scope and extent of radiation hazards and accidents.
- D. Safety Programs:
  1. General description of programs to promote industrial safety at Government, contractor, and licensee installations. Discussion would include explanation of different types of controls between Government and private installations.

Wednesday, March 11 (A.M., possibly part of P.M.)

II. EXAMPLES OF EXPERIENCE AT INDIVIDUAL INSTALLATIONS. Typical examples of operational experience with radiation problems encountered in individual installations. Primary, but not exclusive, focus would be on atomic radiation injury. Discussion would cover measures employed locally at individual installations, Government, contractor, and licensee, to maximize worker safety, including physical and personnel protective measures, instrumentation and monitoring, education and training, and local inspection.

- A. Opening Statement.

B. Experience at Various AEC and Private Installations:
1. Survey of radiation hazards in atomic energy industry.
2. Mines and mills.
3. AEC installations:
a. Employer representative.
b. Union representative.
4. Industrial uses of isotopes.

Thursday, March 12

III. CURRENT FEDERAL, STATE AND PRIVATE ACTIVITIES WITH REGARD TO PREVENTION OF RADIATION ACCIDENTS TO EMPLOYEES. Discussion of measures being employed by the Federal Government, States, and private organizations, to minimize radiation hazards and protect the health and safety of employees, including:

A. AEC and Other Federal Agencies:
1. Regulatory activities.
2. Educational and promotional activities: Description of AEC, HEW, and Labor Department roles.

B. State Activities.

C. Private Activities:
1. Employer programs.
2. Union programs.

Tuesday, March 17 (A.M. and P.M.)

IV. APPLICATION OF WORKMEN'S COMPENSATION LAWS TO RADIATION INJURIES:

Introduction.

A. Main Problem Areas:
1. Coverage of radiation diseases.
2. Medical benefits and supervision of medical care.
3. Statute of limitations.
4. Proof of causal relationship.

Presentations:
Industrial medical representative.
State labor department representative.
Private insurance representative.

B. Existing Laws and Practices:
1. Existing laws and regulations, and their inadequacies.
2. Present methods of meeting inadequacies:
a. AEC experience (chiefly contract operations).
b. Private insurance.
c. State compensation insurance funds.
3. Seminar discussion, to include definition of overall objectives of workmen's compensation and whether they are being met.

Wednesday, March 18 (A.M. and P.M.)

V. Proposed Changes in Laws:
- A. Résumé of Inadequacies and Proposed Changes.
- B. Proposals for Change:
  1. State action (A.M.):
     - a. Council of State Governments representative.
     - b. International Association of Industrial Accident Boards and Commissions (IAIABC).
     - c. Department of Labor and other Federal agency recommendations.
  2. Federal action (P.M.):
     Representatives of AFL–CIO and member unions.

Thursday, March 19

VI. Summary. Round table discussion of important points emerging from the hearings.

CHAPTER 1. REPORT TO THE JOINT COMMITTEE BY THE ATOMIC ENERGY COMMISSION ENTITLED "EMPLOYEE RADIATION HAZARDS AND WORKMEN'S COMPENSATION"

FOREWORD

In a letter dated December 9, 1957, the Executive Director of the Joint Committee on Atomic Energy advised the Commission's General Manager of the intention of the Research and Development Subcommittee to hold public hearings "on workmen's compensation and regulations covering radiation injuries to workers in atomic installations." This letter also requested the assistance of the Commission's staff in making preparations for the hearings, which it was believed, at that time, would be held in the spring of 1958.

During the next several months staff members of the Joint Committee and the Commission met upon several occasions to discuss the probable scope of the hearings. On one of these occasions they were joined by representatives of other Federal agencies, State governments, organized labor, industry, insurance organizations and other interested groups. As a result of these meetings, general agreement was reached on the scope of the hearings, i. e. in terms of areas of interest that would be explored and the factual data that would be assembled in advance of the hearings.

On May 9, 1958, the Chairman of the Research and Development Subcommittee advised the Commission's General Manager that the proposed hearings had been postponed until the 1959 session of the Congress, and requested that the Commission submit to the Joint Committee by January 1, 1959, a report on the major subject areas that had been previously agreed upon. The report which follows has been prepared in accordance with this request.

The General Manager wishes to note the excellent cooperation the Commission has received from outside its own staff in the preparation of this report. He would particularly like to express his appreciation for the excellent contributions made to the report, and later appropriately identified, by Dr. Lauriston S. Taylor of the National Bureau of Standards and Chairman of the National Committee on Radiation Protection and Measurement; by Mr. Arthur W. Motley, Director, Bureau of Labor Standards of the Department of Labor and his staff; by the Commission's consultants, Dr. Shields Warren of the Cancer Research Institute, New England Deaconess Hospital, and Dr. James H. Sterner, medical director of the Eastman Kodak Co.; and by its contractors, the General Electric Co., Phillips Petroleum and Associated Universities, Inc. In addition, the General Manager is indebted to the assistance provided the Commission's staff in connection with the preparation of part V by the Departments of Defense, Commerce.

Labor, Health, Education and Welfare, and the Office of Civil and Defense Mobilization.

It is hoped and believed that the Joint Committee will find this report to be of assistance to it in continuing its preparation for the forthcoming public hearings on this extremely important subject.

PART I

GENERAL BACKGROUND

Introduction

As indicated by the title, this part of the report is designed to provide general background information necessary to an understanding of radiation as a potential industrial hazard. Because radiation has been recognized as a source of occupational injury or disease, standards have been developed over the years governing maximum permissible exposure levels.

The authoritative body in the United States in the field of radiation exposure standards is the National Committee on Radiation Protection and Measurement (NCRP). Section 1 describes the history of this organization and section 2 discusses the historical development of the standards and their underlying philosophy. Both of these sections are abridgements of published articles written by Dr. Lauriston S. Taylor, Chief, Atomic and Radiation Physics Division, National Bureau of Standards, and the Chairman of the NCRP. Their abridgement, and incorporation in this report have been authorized by Dr. Taylor.

Section 3 discusses in general the scope of the Federal Government's research program bearing upon or related to the standards, with more detailed treatment being given to the research programs of the AEC. Section 4 discusses the origin and nature of industrial hazards and radiation injury.

Section 1. The National Committee on Radiation Protection and Measurements [1]

INTRODUCTION

The National Committee on Radiation Protection and Measurements was established in the United States in 1929, since which time it has provided the basic standards and guidance in the field. Through the cooperation of many organizations this has proven to be an effective program. At the same time through interlocking membership between the NCRP and the International Commission on Radiation Protection, the views of this country have been integrated into the world views. A brief description of the activities of the NCRP and its reports is presented in this section.

[1] This section is an abridgment and updating of an article written by Dr. L. S. Taylor and published in "Health Physics," Pergamon Press, 1958, vol. 1.

FORMATION

The roots of the National Committee on Radiation Protection and Measurements go back to 1928 and are intimately related to the formation of the International Commission on Radiological Protection in July of that year. With the possibility in mind of forming an international organization on radiological protection, the Second International Congress of Radiology, before meeting in Stockholm in July 1928, invited several countries to send representatives to the Congress for the purpose of discussing protection problems and possibly preparing some initial X-ray protection recommendations. From the United States, L. S. Taylor was designated as representative of the National Bureau of Standards, and one representative each attended for the American Roentgen Ray Society and the Radiological Society of North America.

When attempts were made to reach agreement between the United States and other countries, serious difficulties arose. Each of our two radiological societies offered different recommendations and each claimed to be the authoritative body. The NBS had no recommendations to offer and was there more by way of an observer. As a result, the recommendations that were in fairly acceptable form, prepared by the British protection committee, were adopted as the first international recommendations. In the process, the United States delegates showed up rather poorly, in that agreement could not be reached on who authoritatively represented the views of the United States.

Concurrent with the meetings of the Congress, G. W. C. Kaye and Stanley Melville (Great Britain) and L. S. Taylor (United States) set about to organize a permanent structure for an international organization. After preliminary discussions, during which some general rules of organization were developed, the International Commission on Radiological Protection [2] was organized.

It was agreed that the Commission should be kept small, and that wherever possible, representatives to the Commission should be chosen from National Laboratories where such laboratories existed in member countries. This arrangement and the general philosophy of operation of the Commission was approved by the Second International Congress of Radiology before the close of its sessions.

Because of the confusion regarding accredited representation, introduced primarily by the United States but also by Germany and to a lesser extent by France, the chairman of the ICRP, Dr. G. W. C. Kaye, recommended that a single central committee be established within those countries having more than one radiological organization for the purpose of consolidating national recommendations for presentation at the next meeting of the Commission. It was suggested that the members of the ICRP take this up individually with the various groups in their countries.

As the U.S. representative to the international protection group, it became the responsibility of L. S. Taylor to convey its recommendation to the various groups involved in this country, to convince them of its soundness, to obtain their approval and suggestions, and to

[2] Until 1946, the Commission was called the International X-ray and Radium Protection Committee.

organize a national committee which could deal most effectively with the protection problems faced at that time.

As a result of discussions in the fall of 1928 with officers of the American Roentgen Ray Society and the Radiological Society of North America, it was agreed to consolidate their protection activities into a single committee. They further recommended that the committee's activities be centralized at the National Bureau of Standards for the following reasons:

(1) It had by that time established a definite long-range program in the general field of radiation protection.

(2) It had the only laboratory in the country having as its primary interest the development of radiation-protection data and information.

(3) It had no inter-society or political ties and therefore could be expected to retain an independent position and viewpoint.

(4) It provided the official U.S. representative to the International Commission on Radiological Protection.

The two radiological societies each recommended a physicist and a radiologist for membership in the proposed national committee and the American Medical Association appointed a member to represent its viewpoints. It was also felt that representation of the X-ray equipment manufacturers would be desirable and each of the manufacturers was asked to nominate candidates for this representation. Of the nominations received, the manufacturers then chose two to serve as their representatives.

Thus, early in 1929, the initial organization of the Advisory Committee on X-ray and Radium Protection was established with L. S. Taylor acting as chairman and with the following participating organizations: American Roentgen Ray Society, Radiological Society of North America, American Medical Association, X-ray Equipment Manufacturers, National Bureau of Standards, and ICRP.

HISTORY

The first meeting of the committee was held in September 1929, during the annual meeting of the American Roentgen Ray Society. As its first objective, the committee undertook the preparation of recommendations on X-ray protection. These were published on May 16, 1931, as National Bureau of Standards Handbook 15.

The next effort was directed towards the preparation of recommendations on radium projection, and the first handbook on radium protection, NBS Handbook 18, was published March 17, 1934.

Soon after the publication of Handbook 15 on X-ray Protection, very rapid developments were made in the X-ray field; by 1934 or 1935 it was recognized that this handbook would have to be revised. The revised recommendations were issued in July, 1936 as NBS Handbook 20.

In this handbook, there appeared for the first time the recommendation of a specific permissible exposure level (then called tolerance dose) of radiation that could be allowed for occupational exposure. The figure recommended was 0.1 r/day. This permissible exposure level remained in force for 12 years and was used by the Manhattan Engineering District in its operations. It was subsequently changed as a result of NCRP action in about 1948.

The revision of Handbook 18 on radium protection was next undertaken and the new handbook (H23) was issued August 25, 1938.

These two handbooks, H20 and H23, were accepted in this country as the primary guides for protection against X-rays and the radiations from radium. As noted above, they were also the primary guides in this field to the Manhattan project.

Through the war years, there was no formal activity by the Advisory Committee. During the time, however, most of the members of the Advisory Committee were drawn into the MED program and it was largely through their efforts that uniform safety regulations prevailed during that period.

During its early activities, it was customary for the full committee to work together on the development of protection recommendations. When completed, the recommendations were submitted through their respective representatives to the participating organizations for noting and approval. Formal approval was usually given at one of the regular business meetings of the societies. With the NBS as one sponsor of the committee, the recommendations were published by the Government Printing Office as National Bureau of Standards Handbooks thus receiving the usual NBS editorial processing.

In September 1946, an informal meeting of the Advisory Committee was held to discuss the extensive revision needed in the X-ray protection recommendations, particularly in the upper voltage regions. At this meeting, it was pointed out that protection problems had become too complex to permit their study and solution by the committee as then constituted. It was recommended that steps be taken to secure the participation in this work of additional groups such as the MED and U.S. Public Health Service, Military Department, etc. As a result in October 1946, Dr. S. L. Warren and Dr. K. Z. Morgan were appointed as representatives of the MED and the USPHS named Dr. H. L. Andrews and Dr. E. G. Williams.

The first normal postwar meeting of the Committee was held on December 4, 1946. In the agenda for this meeting, it was pointed out that new data had become available since the issuance of the recommendations on X-ray protection and that many new protection problems had arisen with the rapid expansion in the radiation field (protection against neutrons, multi-million volt X-rays, radioactive isotopes, etc.). It was suggested that the scope of the work be defined; and that consideration be given to organizing small working groups to deal with each of the problems, their completed reports to be submitted to the committee for approval.

ORGANIZATION

At the December 4, 1946, meeting, it was agreed that the Committee should be substantially enlarged and reorganized. At the same time, it was felt that the name of the Committee should be made more inclusive and it was therefore renamed National Committee on Radiation Protection. The National Bureau of Standards was reaffirmed as the central coordinating agency for the work of the Committee; sponsorship by an impartial agency was felt to be particularly advantageous in view of the various types of participating organizations (radiological societies, industry, government, and the possible inclusion of industrial and labor groups).

The general organization and operational procedures outlined below were agreed upon at this meeting, and have been the basis for the continuing operation of the Committee:

(1) The Committee would consist of an Executive Committee, Main Committee and as many subcommittees as necessary to consider the problems that come within the Committee's scope.

(2) The Executive Committee would be composed of five members appointed by the chairman and subject to the approval of the Main Committee. The Committee chairman would act as chairman of the Executive Committee.

(3) The Main Committee would be composed of (*a*) technically qualified representatives appointed by organizations interested in the scientific and technical aspects of radiation protection, (*b*) representatives at large whose services are felt to be of special value, appointed by the Executive Committee, and (*c*) chairmen of subcommittees.

(4) The choice of chairmen and members of subcommittees would not be restricted to members of the Main Committee but would be based on the particular qualifications needed for the work.

(5) The final report of the subcommittee would be submitted to the Executive and Main Committees for approval. Because of the high degree of success of the NBS Handbook series, it was recommended that this mode of publication and distribution to the public be continued.

Because of the reorganization and enlargement of the Committee, the chairmanship was thrown open for reconsideration. L. S. Taylor was nominated and approved by vote to continue indefinitely in this capacity.

It was agreed to establish the following subcommittees:

(1) Permissible external dose.
(2) Permissible internal dose.
(3) X-rays up to 2 Mev.
(4) Heavy ionizing particles (neutrons, protons and heavier).
(5) Electrons, radium, and X-rays above 2 Mev.
(6) Radioactive isotopes, fission products, including their handling and disposal.
(7) Monitoring methods and instruments.

Since then the following additional subcommittees have been established:

(1) Waste disposal and decontamination;
(2) Protection against radiations from Ra, Co^{60} and CS^{137} encapsulated sources;
(3) Regulation of radiation exposure dose;
(4) Incineration of radioactive waste;
(5) Electron protection;
(6) Safe handling of cadavers containing radioactive isotopes;
(7) Permissible exposure doses under emergency conditions;
(8) Standards and measurement of radioactivity for radiological use;
(9) Standards and measurement of radiological exposure dose;
(10) Standards and measurement of absorbed radiation dose;
(11) Relative biological effectiveness.

With the formulation of these basis philosophies, the Committee began its active-program.

Appendix A–1 contains a list of handbooks published to date.

Appendix A–2 contains the NCRP membership list showing the present representation, subcommittee structure, and complete membership.

SECTION 2. HISTORICAL DEVELOPMENT OF RADIATION EXPOSURE STANDARDS [3]

INTRODUCTION

The main purpose of this section will be to explain the background of the problem of protection against the harmful effects of radiation. With an understanding of this it should be easier to apply the protection measures prescribed by various responsible bodies for the solution of specific problems. Protection cannot be adequately supplied by rule alone—any rules should be regarded mainly as guides, and should be freely supplemented by good judgment, commonsense and a full understanding of the end objectives.

Most radiation workers are aware, at least in a general way, of the existence of so-called "maximum permissible limits of radiation dose"; what is not so certain, is their understanding that these levels are to be regarded as maximums, and not as levels which should be applied without further question to the whole population or even the much smaller group of radiation workers.

For the last 30 years the International Commission and related national bodies have, without exception, emphasized the need for working as far below the maximum as circumstances permit. Part of the reasoning behind this emphasis was the strong feeling, based upon very limited evidence, that it might be necessary to establish lower permissible levels when the fraction of the population exposed becomes substantially larger. That time is now approaching.

Another part of the reasoning was based upon sheer prudence, with the knowledge that aside from medical applications, no radiation is good for man.

The possibility of the lowering of the permissible exposure levels has been mentioned. Such lowerings have occurred in several major steps since the first quantitative limits were established by the ICRP in 1934. The reasons for this have been various and, except for the most recent change, will not be discussed in any detail. Suffice it to say that the principal factors have been, first, an improved knowledge of radiation effects on the human system and second, the engineering developments that have made it possible much better to confine the undesired radiation, in spite of the much greater quantities being used.

It may perhaps sound startling to contend that the establishment of permissible levels of radiation exposure is not basically a scientific problem. Indeed, it is more a matter of philosophy, of morality, and of sheer wisdom. True, the basic knowledge used in establishing radiation levels is derived from scientific sources, and by and large

[3] This section is an abridgment of an article written by Dr. L. S. Taylor which appears in "Health Physics," Pergamon Press, vol. 1. The article was first delivered as a lecture at the UNESCO International Conference on Radioisotopes in Scientific Research held in Paris on September 10, 1957, and is believed by Dr. Taylor to represent the views of the International Commission on Radiological Units and Measurements, and the U.S. National Committee on Radiation Protection and Measurement.

the use and application of this knowledge must be by scientists, drawn from many fields of endeavor. Also, the achievement of the protection goals is purely a matter of science and engineering.

But before a maximum permissible dose of radiation can be set for man, there must be an unequivocal answer to one question: "what amount of radiation may man receive in either chronic or acute exposure without any harm to himself or his progeny?" At present the only answer to this question is: "None." There is today little or no direct, positive proof that there does or does not, exist some level of exposure below which harm will not result. It was recognition of this lack of proof that led the ICRP many years ago to discard the term "tolerance dose" which implied that there was some degree of irradiation that was wholly without harm. In its place is used the term "permissible dose," which, while not completely unobjectionable, does not carry the connotation of absolute safety.

There are then, two factors that remove radiation protection from the field of science to the field of philosophy: (1) lack of a clear and scientifically unobjectionable answer to the question posed above, and (2) the consequent necessity for assuming that any amount of radiation, no matter how small, is harmful.

In spite of the lack of direct knowledge of radiation effects on himself, man has recognized and become accustomed to the advantages that radiation offers him, both as to his health and his material well-being. These will not be given up lightly—probably will not be given up at all.

PHILOSOPHY OF RISK

The problem centers about a philosophy to which mankind is well accustomed; it may be called a "philosophy of risk." In nearly every phase of ordinary life man accepts knowingly if he thinks about it at all, risks of commission that could cost him his life. These risks are accepted in the belief that the possibility of gain offsets the chance of loss. One naturally makes every attempt to reduce the element of risk to a minimum, but in rare instances only can it be reduced to zero. To attain zero risk it is almost certain that life itself would have to be given up. Mankind is thus continually in a situation of having to effect a suitable compromise between risk and gain. The effectiveness with which conditions can be weighed and compromises made depends upon knowledge of both items—risk on the one hand, and gain on the other.

For emphasis some of the risks that are commonly accepted can be mentioned: virtually any mode of transportation from boat or bicycle to the airplane—but without these, life today would be very different indeed; smoking, a luxury that all could well do without—except that some other relaxing habit that would be just as dangerous would be found; many forms of medication to which there are dangerous individual idiosyncrasies or allergies.

In essence, radiation risk is no different from the rest of these except for the very important aspect of its probable mutagenic effect that will continue for generations. But there are accepted risks of other nature which may also have some small mutagenic aspect.

With the direct knowledge of the biological effects of radiation, it is still fairly clear that radiation offers direct advantages to health or material well-being. In the area of health, it is certain that radiation

techniques have contributed most importantly to greatly increased life expectancy. But simultaneously contributions also have been made by antibiotics, drugs, surgery and so on to the point where it is probably impossible to ascribe cause and effect to any one. In industry, radiation as an examining tool, is used to detect the imperfections of parts, the failure of which might cost lives. In research, radiation has offered whole new avenues of approach to the solution of problems essential to growth of knowledge. The advent of nuclear power may have come just in time to alleviate critical power shortage in some countries, and create sources of power in countries that had no power at all. But each of these uses has its own quota of risk to someone. Although it is generally agreed that they should not be given up, there should nevertheless be a continuing struggle to push the risk to still lower levels.

RADIATION DAMAGE TO MAN

In comparison with the gains, the risks from radiation use are not very clear and are particularly difficult to define on a cause and effect basis. Except in relatively rare instances, there is almost no knowledge relating death, shortening of life expectancy or genetic abnormalities in man to a specific dose or a particular radiation exposure. It is unfortunate, for analytical purposes, that practically any radiation effect can also be caused by other means, known or unknown. Most radiation effects can be detected only by statistical studies on relatively large population samples.

The two main general types of radiation damage to man are somatic and genetic. Until about 10 years ago, the main emphasis was given to somatic damage—that is damage to the body cells of the individual exposed. The basic protection criterion had been to set the exposure levels sufficiently low so that no detectable damage to the individual would result. The possibility of genetic damage was not overlooked, but too little was known about it to permit of its sensible evaluation. Particularly in the light of present knowledge there is a very real question as to what constitutes "detectable damage." Certainly a skin lesion is detectable but a similar lesion within the body might pass undetected forever. If undetected damage exists and the individual dies from seemingly normal causes, who is to say whether or not that damage may have contributed in some obscure way to that death? In fact there is increasing evidence based on animal experiments that there is such a relationship.

Up to now there has been little, if any, acceptable evidence that chronic exposure to radiation at the levels prescribed since 1934 has resulted in definable or detectable damage. It would appear, but no more than appear, that the permissible exposure levels have always been adequately low from the point of view of specific somatic damage.

The possibility of genetic damage has been known for some 25 years, but, as already mentioned, knowledge of this was very qualitative until a few years ago. Even now most of it is based on animal experiments—human experience is extremely limited—but the burst of effort in studying the genetic effects of radiation over the past 10–15 years has substantially enhanced man's knowledge of the subject. Particularly within the past few years the emphasis on genetic effects

has increased enormously—some fear it to be out of proportion to the importance of other radiation effects.

The treatment of the genetic problem is one requiring the utmost in wisdom and morality. For, whatever the effects of radiation on genetic status may be, its principal impact will not be upon the generation of individuals exposed. Rather will it be distributed over future generations up to perhaps 50 in number. Whether the effects on these future generations are to be good or bad—and on the average the prediction is bad—the control of that future lies in the hands of those living today. The dilemma is complicated by the fact that there may never be a means by which the cause and effect can be clearly established. Deleterious mutations due to irradiation of persons at presently accepted levels may only be a fifth of those resulting from all causes—the other four-fifths may be spontaneous, or of unknown cause. To what degree are today's generations to be held responsible for known contribution to this legacy for the future? What is the moral obligation in this regard? The answer is clear: To be morally right though ignorant, man must do all in his power to reduce genetic damage to a minimum, commensurate with continued use of radiation as an immeasurable valuable servant. A workable balance between risk and reward must continually be sought, and is being sought. The recommendations of the ICRP in 1956, based on their earlier findings beginning in 1952, reflect this balance within the scope of present knowledge and technical capabilities.

The geneticist contends that zero radiation exposure to man, apart from the natural background radiation, would be the ideal goal, and though as yet unproven he may well be right. This of course means the complete discontinuance of all radiation use—an unacceptable alternative. The problem thus confronting mankind is to determine or, perhaps better, to decide how much above zero to operate. The levels presently recommended by the ICRP reflect the best decision on this delicate question that can be reached today. Tomorrow it may be possible to make a wiser decision.

COMPARISON OF THE NEW WITH FORMER STANDARDS

The new levels of radiation exposure may have caused temporary hardship to operators in some areas, but on the whole it is not believed that they seriously interfere with major and worthwhile uses of radiation. They have involved some reeducation in the technological world, and some new education for the public. The fact that the permissible exposure levels could have been lowered by a factor of three below those of 10 years ago is a tribute to the world's radiation industry. Its technological advances over that period have been one of the most important factors in lowering these levels.

The latest levels recommended by the ICRP average about 5 rems/year for occupational exposure.[4] From 1950–56 the average was about 15 rems/year; from 1934–50 the average was 60 rems/year (in the United States the National Committee on Radiation Protection in 1935 recommended 30 rems/year); prior to 1934 the levels were of the order of 100 rems/year. Table 1 below compares these levels.

[4] The terms used in radiation dose measurement are defined in sec. 4 of this part.

TABLE 1.—*Permissible occupational exposure levels*

	Level (rems/year)
ICRP (April 1956)	5
ICRP (1950–1956) at 0.3 rem/week	15
NCRP (1935–1948) at 0.1 rem/day	30
ICRP (1934–1950) at 0.2 rem/day	60
Prior to 1934	100

At none of these levels has there ever been developed any positive evidence of damage to the individual. In the main, these successive lowerings represent improved compromises between goal-zero, and capability. Again capability has been made possible by technological advances.

Of course, the objectivity of damage criteria is marred by the possibility of a shortened average life span which, if real, must be classed as damage. Recent studies of the life shortening of radiologists are now considered by some to be inconclusive in the quantitative sense, but it is generally believed that there must be some such effect on man. The estimates vary so enormously as to cast doubt on all of them.

In all of the considerations by the ICRP there has been no assumption of any kind of threshold level below which specific or general radiation damage does not occur; in the absence of any positive knowledge, this seemed the only acceptable conclusion. This is not to imply that there may not be some specific thresholds, though at the moment the possibility seems remote. Statistical data such as that recently obtained for leukemia incidence, while not completely free from objection, points to the conclusion that there is no threshold.

Thus all indications seem to point to the fact that present and future solutions of the radiation protection problem will have to be based on a risk philosophy, will have to be compromise solutions, and cannot be solved on the basis of scientific evidence alone.

At this point one may well ask why so much emphasis has been placed on a discussion of the background philosophy of radiation protection. The purpose has been to emphasize the fact that protection against the harmful effects of radiation is not a straightforward problem for which there is a simple black or white solution. A degree of protection can be had—the exact degree depends upon those who use radiation. Rules provide some basic guidance as to limits which may be regarded as acceptable today, but should never be considered as ideal. Continuous efforts must be applied toward working with lower levels—as low as possible commensurate with the task. The extent to which these efforts are successful may very well affect the whole future use of radioactive isotopes and nuclear power.

THE ICRP 1956 RECOMMENDATIONS

The radiation exposure levels recommended by the ICRP in April 1956 were not made capriciously, but were the result of studies begun in 1952, at which time the ICRP had arrived at essentially the same conclusions as those reached 4 years later. However in 1952 they felt that existing data were inadequate and the problem insufficiently urgent to warrant hasty action. While knowledge had not increased enormously since then, the urgency had increased to some extent because of the more widespread use of radioactive materials, and

because of the public concern over fall-out and the development of nuclear power.

The new levels were dictated mainly for reasons of genetic damage, but it must now be recognized that somatic damage possibilities are assuming equivalent importance. As already mentioned, the direct evidence of genetic damage to man is almost totally lacking, and that of somatic damage is very scant at best.

In terms deliberately general, the ICRP made two principal recommendations on the maximum permissible dose: (1) for the population as a whole, the average per capita dose should not exceed 10 rems, from conception up to age 30 (and by inference one-third of this amount per decade thereafter); (2) for radiation workers, the individual occupational dose should not exceed 50 rems up to age 30 (and by inference again this same amount per decade thereafter). It is obvious that these need further interpretation. For that purpose the most recent interpretation made by the National Committee on Radiation Protection in the United States is discussed. Appendix A–3 contains the April 15, 1958, Statement of the NCRP entitled "Maximum Permissible Exposures to Man." This statement was issued as an addendum to NBS Handbook No. 59 originally issued September 24, 1954, and entitled "Permissible Dose from External Sources of Ionizing Radiation."

INTERPRETATION BY THE NCRP

Dealing only with the problem of occupational exposure, an allowance of 50 rems up to age 30 implies an average of about 5 rems per year, assuming 10 working years. For fairly obvious reasons it is impractical to integrate a person's dose over a period as long as 10 years. Since genetic damage was a primary consideration in setting the new levels, it is important to limit the gonadal dose as much as possible in the years during which most children are conceived. Thus it would be desirable to delay the exposure as long as possible—at worst to distribute it nearly uniformly at the rate of 5 rems per year.

This solution, however, is not without its difficulties because this Nation's legal machinery is accustomed to dealing with the individual and not with averages. The difficulty in dealing with an "average number" is introduced because of the fact that the safety recommendations of a few years ago are now becoming legal requirements backed up by varying degrees of enforcement or pressures. During the 25 years beginning in about 1930, radiation safety the world over, was based on the ICRP recommendations backed up by voluntary compliances and good sense. It must be admitted that there have been times when neither compliance nor good sense prevailed, but in the vast majority of situations they did. The tendency now is for governments to call for strict codification and the development of radiation protection regulations wherein a situation is either black or white. Here is where the difficulty begins.

If the limits are said to be an average dose of 5 rems per year, but not more than 50 rems in, say, 10 years it is meant to mean just that. However, it is known that there is little difference if a person is allowed to receive, say, 7 rems in one year and 3 rems in the next as compared with 5 rems in each year. On the other hand it would clearly be wrong to allow a person of age 28 to receive, say, 25 rems in

each of 2 successive years. It would be even more wrong to deliver such doses to a person, say, of age 20.

To illustrate the difficulty, suppose the limits are said to be an average of 5 rems per year. Legally this will be interpreted as no more than 5 rems per year. Everything must be black or white and any individual who has been so unfortunate as to have recorded against him a dose of 5.001 rems, might believe he had legal grounds for redress from his employer. This is sheer nonsense if on no other grounds than the fact that his significant dose cannot actually be measured with an error of less than ± 10–20 percent. Yet it is difficult to evolve a law in this field where there is adequate latitude for ordinary reasonableness.

Consider the cost to plant operation if a legal limitation of 5 rems per year is put upon the individual worker. Plant management would be foolish to plan its operations in such a way that part or all of its workers would be allowed to take a dose closely approaching 5 rems per year. Experience has demonstrated that one or two people are bound to exceed this, and even though it is known that a slightly higher exposure is without harm, the employee might seek redress. Because of this fear, the plant must plan its operation so that, in general, no employee can receive more than say 40 or 50 percent of the permissible exposure. This can be very costly and could seriously retard the atomic energy industry.

Where sufficient assurance can be provided that monitoring and recording methods are adequate, the widest latitude in the use of permissible exposure levels should be allowed. It is not known how this can be worked out legally but it seems fairly certain that in operations of any substantial size, it would pay the employer to have adequate measuring and recording systems, and then to be allowed wide latitude in his use of the recommended permissible levels.

The main difficulty may occur with the small users of radiation sources where there is transient employment and where the cost of monitoring equipment may be incommensurate with the cost of the operation. For such users, permissible exposures integrated over 1 week, or, at the most 3 months, would in all probability be the most feasible.

This problem may be overcome by means of a simple formulation relating a total permissible accumulated dose to the age of the individual. This interpretation says that at any age of 18 or over, the individual may be allowed to accept a dose such that his total accumulation in rems will not be in excess of 5 times the number of years over 18. The age of 18 is the youngest at which a person in the United States may be employed in radiation work. This age limit may be different in other countries.

The following is the exact statement by the NCRP:

> *Accumulated dose.*—The maximum permissible accumulated dose, in rems, at any age, is equal to 5 times the number of years beyond age 18, provided no annual increment exceeds 15 rems. Thus the accumulated MPD=5 (N−18) rems where N is the age and greater than 18. This applies to all critical organs except the skin, for which the value is double.

The interpretation given above implies that when a person starts radiation work for the first time, at some age over 18, he will be able to accept a higher dose per year provided that (1) it does not exceed 15 rems and (2) he does not exceed his age prorated maximum. This

means essentially that the individual has built up a reserve of permissible exposure. But such a concept if exploited, carries certain obvious dangers. On the other hand, if every individual in an operation carries some reserve, it will unquestionably make for simpler and more economical protection procedures.

The principle should not be exploited to the point where persons are required to accept radiation exposure that may with reasonable care be avoidable.

The age proration principle automatically holds down the exposure at the younger ages where it is most critical. It gives leeway at the older ages where it is less critical.

This principle places somewhat of a premium upon the employment of older persons with little or no radiation exposure history, especially for tasks involving unavoidable exposure at levels above the average. However, the age prorated maximum is overridden by the yearly maximum which should not be exceeded. While an operator may never want to avail himself of the flexibility inherent in the age proration principle, its existence offers particular advantages as well as insurance in special circumstances.

APPLICATION OF THE MPD FORMULA

Application of the principle is illustrated in figure 1, appearing on page 15. The area under curve A illustrates the region within which a person's accumulated dose must be contained under the new requirements. The broken curves drawn in this area show hypothetical illustrations of how the dose principle may be applied in individual cases. The maximum by age 60 would be 210 rems.

The region below curve B shows the comparable dose limits under the provisions that have applied in the U.S.A. from 1947 to 1957. Here at age 60 the maximum would have been 630 rems.[5]

The region under curve C shows the limits recommended in the U.S.A. between 1935 and 1947. The total at age 60 could have been 1260 rems.

For about the same period of 1934–50 the maximum permissible accumulated dose as recommended by the International Commission on Radiological Protection could have been as high as 2520 rems by age 60—or more than 10 times the present new levels.

For design or planning or operational purposes, plants may wish to use average weekly, monthly or quarterly levels and to do their monitoring accordingly. Under the NCRP interpretation this is permitted. Where it is desired to keep monitoring and recording procedures to a minimum, it would probably be wise, in many cases, to operate on a weekly or monthly basis anyway. The choice of procedure depends largely upon (1) the economics of any particular situation and (2) the margin of uncertainty that would be introduced in the recorded accumulated dose of the individual. Where a person's exposure in prior employment may be unknown or undocumented he is presumed to have had the maximum dose permitted up to his particular age.

The levels discussed above need not be modified by the addition of one emergency exposure of 25 rems during that person's lifetime.

[5] This does not include the possibility of doubling the weekly dose at age 45. If this is included the accumulated dose up to age 60 could be as high as 850 rems.

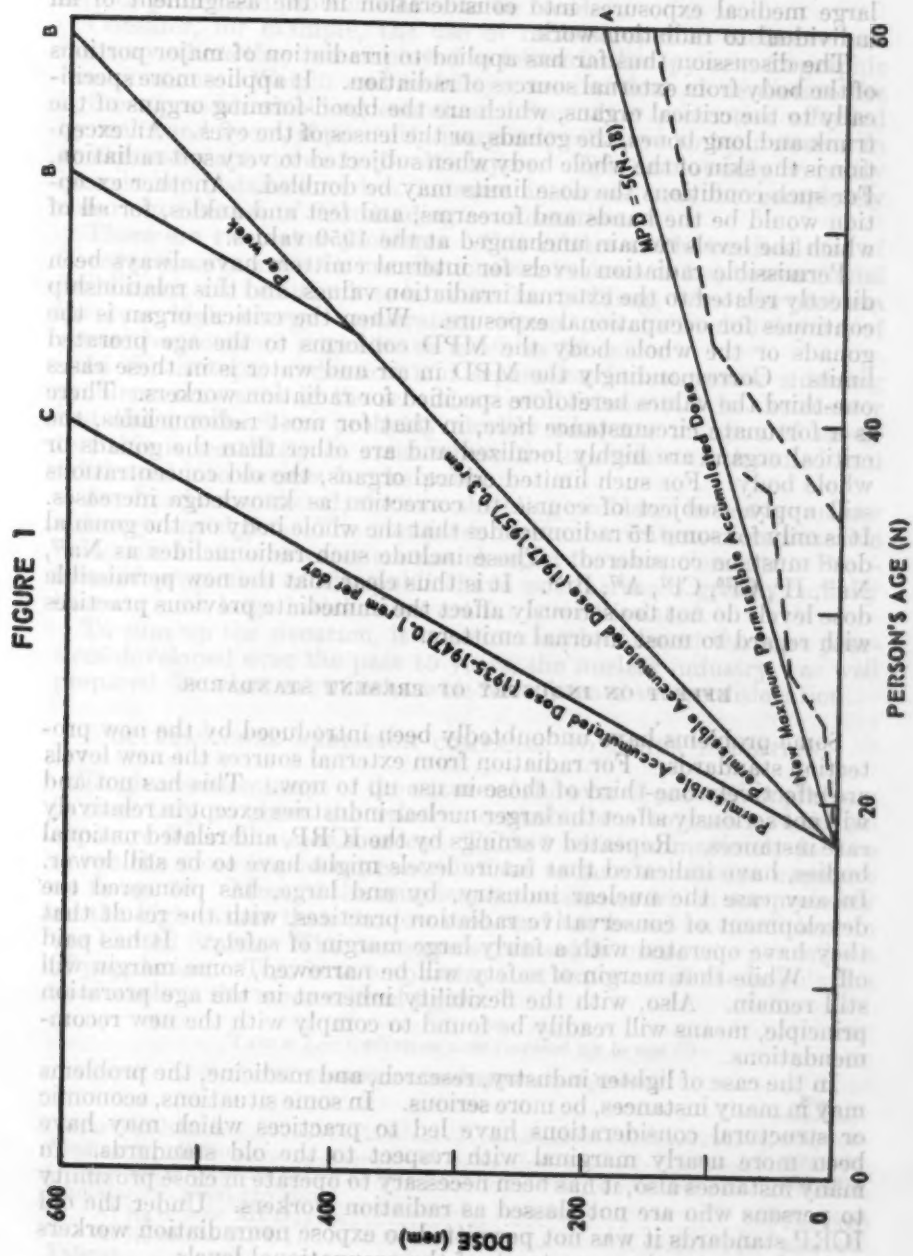

A
B
B
C
MPD = 5(N-18)
New Maximum Permissible Accumulated Dose
Permissible Accumulated Dose (1947-1957) 0.3 rem
Permissible Accumulated Dose (1933-1947) 0.1 rem per day
per week
DOSE (rem)
PERSON'S AGE (N)
600
400
200
0
60
40
20

FIGURE 1

Also it might be noted that these exposure levels are not modified by any radiation exposure received for medical reasons. On the other hand, it would be prudent for the employer to take any especially large medical exposures into consideration in the assignment of an individual to radiation work.

The discussion thus far has applied to irradiation of major portions of the body from external sources of radiation. It applies more specifically to the critical organs, which are the blood-forming organs of the trunk and long bones, the gonads, or the lenses of the eyes. An exception is the skin of the whole body when subjected to very soft radiation. For such conditions the dose limits may be doubled. Another exception would be the hands and forearms, and feet and ankles, for all of which the levels remain unchanged at the 1950 values.

Permissible radiation levels for internal emitters have always been directly related to the external irradiation values, and this relationship continues for occupational exposure. When the critical organ is the gonads or the whole body the MPD conforms to the age prorated limits. Correspondingly the MPD in air and water is in these cases one-third the values heretofore specified for radiation workers. There is a fortunate circumstance here, in that for most radionuclides, the critical organs are highly localized and are other than the gonads or whole body. For such limited critical organs, the old concentrations still apply—subject of course to correction as knowledge increases. It is only for some 15 radionuclides that the whole body or, the gonadal dose must be considered. These include such radionuclides as Na^{22}, Na^{24}, H^{3}, Cl^{36}, Cl^{37}, A^{37}, Br^{82}. It is thus clear that the new permissible dose levels do not too seriously affect the immediate previous practices with regard to most internal emitters.

EFFECT ON INDUSTRY OF PRESENT STANDARDS

Some problems have undoubtedly been introduced by the new protection standards. For radiation from external sources the new levels are effectively one-third of those in use up to now. This has not and will not seriously affect the larger nuclear industries except in relatively rare instances. Repeated warnings by the ICRP, and related national bodies, have indicated that future levels might have to be still lower. In any case the nuclear industry, by and large, has pioneered the development of conservative radiation practices, with the result that they have operated with a fairly large margin of safety. It has paid off. While that margin of safety will be narrowed, some margin will still remain. Also, with the flexibility inherent in the age proration principle, means will readily be found to comply with the new recommendations.

In the case of lighter industry, research, and medicine, the problems may in many instances, be more serious. In some situations, economic or structural considerations have led to practices which may have been more nearly marginal with respect to the old standards. In many instances also, it has been necessary to operate in close proximity to persons who are not classed as radiation workers. Under the old ICRP standards it was not permitted to expose nonradiation workers to levels greater than one-tenth of the occupational levels.

It has not been finally decided whether the non-occupational levels will be one-tenth of the new levels or remain at one-tenth of the old levels, but if the average nonoccupational dose for somatic as well as

genetic reasons is to be held down adequately it may be necessary to work to one-tenth of the new standards. Since this is only 3 to 5 times the natural background radiation at sea level, it is obvious that serious protection problems have to be faced.

Consider, for example, the use of radioisotopes in medicine and industry where they are employed in telecurie therapy or radiographic examinations. Weight and mobility considerations alone dictate the lightest possible shielding container. Secondary protection afforded by walls and floors, if presently marginal, will have to be increased in thickness by about two half-value layers. This cannot only be costly in existing installations but in some instances may be completely ruled out because of floor-loading considerations.

There are two other problems. One relates to the medical use of X-rays; since many such installations are in more or less conventional buildings it will be difficult to increase the shielding. Another problem involves high energy accelerators where two half-value layers of protective concrete might be as much as 30 cm.

In the isotope production and separation industry new shielding problems may arise in the secondary establishments. In the reactor installations there are probably already adequate margins of safety but this is less likely in areas where the materials are handled and fabricated into devices for the public.

As already mentioned, the new shielding problems in heavy nuclear industry are slight. The standards for concentration of radioactive materials in air and water are not changed for most elements. Problems of protection of the public have not increased greatly, mainly because most large installations are fairly well isolated.

To sum up the situation, it appears that because of the wise practices developed over the past 15 years, the nuclear industry was well prepared for what might otherwise have been a severe dislocation.

OCCUPATIONAL RADIATION COMPARED TO OTHER RADIATION

To give some concept of the nature of the overall protection problem it may help to show the relative contributions to man's radiation exposure from all major sources. Table 2 which immediately follows shows the more important contributions to man's radiation exposure up to age 30. Most of the numbers are estimates which are probably on the high rather than the low side, and are based on conditions in the United States. The doses are expressed in man-rems per million of population. This is to emphasize that exposure of the population as a whole is the more critical figure.

TABLE 2.—*Radiation dose received up to age 30*

[MPD=14,000,000 man-rems per million persons]

	Dose (man-rems)
Natural radiation	4, 000, 000
Medical irradiation	5, 000, 000
Occupational exposure	150, 000
Radiation in plant environs:	
At 1/10 of new MPD	(150, 000)
At 1/10 of old MPD	450, 000
Fallout	200, 000
Total	9, 800, 000
Balance	4, 200, 000

The ICRP recommends that the average per capita dose for the whole population should not exceed 10 rems up to age 30. This is in addition to the natural background of about 4 rems over the same period. Thus the total permissible does would amount to 14,000,000 man-rems per million persons.

The dose from natural radiation acts over the full 30 years on the whole population and will contribute 4,000,000 man-rems.

Medical irradiation is averaged over the whole population for 30 years, and in the U.S.A. might possibly be as high as 5,000,000 man-rems. Occupational exposure at an average of 5 rems/year acts on one-fourth of a percent of the population over a period of 12 years, up to age 30, and contributes 150,000 man-rems.

Irradiation of nonradiation workers in the environs of radiation sources, might conceivably act on 1 percent of the population for an average of 30 years, though this seems highly unlikely in the forseeable future. At a level of one-tenth of the new occupational levels this would contribute 150,000 man-rems. At one-tenth of the old levels the contribution would be 3 times as large, or 450,000 man-rems.

Fallout radiation would act on everyone for 30 years, and, at double the current rate, would contribute 200,000 man-rems.

It is important not to be complacent about the seemingly low contribution to man's total dose from occupational exposure. For the individual, it still amounts to 50 rems each 10 years, and this is over 5 times higher than the average per capita dose for the whole population. It is however, to be accepted like any other occupational risk in industry.

The total from all sources is 9,800,000 man-rems, leaving a balance of roughly 4,000,000 man-rems. Some of this balance will be consumed by the use of radioactive household devices, nuclear power, etc. However, it should not be used up simply because it appears to be there. It is still necessary to operate on the principle that no radiation taken by man unnecessarily is good for him. Rather than try to use up our radiation reserve, an endeavor should be made, by all means possible, to increase it.

Section 3. Scope of Current Research Efforts Bearing on Present Exposure Standards

INTRODUCTION

The Federal Government's research programs on radiation effects are oriented toward the objectives of keeping pace with the expanding civilian uses of atomic energy. In its own operations, the Commission must be prepared through the results of research to cope with exposure of personnel to penetrating rays from a reactor, a particle accelerator, or radiation emitted from large quantities of radioactive materials. It must likewise be able to meet emergencies arising from the accidental ingestion or inhalation of hazardous or potentially hazardous materials. There must therefore be a continual increase in the collection and dissemination of information on the effects on the body and specific organ systems of short-term and long-term radiation exposures.

PRINCIPAL AREAS OF RESEARCH

The Commission's research program and the related programs of other Federal Agencies in radiation protection and the study of radiation effects on man encompass many scientific disciplines. These include not only biology, medicine, biophysics, biochemistry, but also meteorology, geology, hydrology, and the agricultural sciences, as well as others. These programs are carried out in Government laboratories and under contracts with universities, hospitals, nonprofit organizations, and industrial organizations. Important categories of research programs are the following:

(*a*) Radiation effects on the body (whole body and parts of the body) including such effect as cancer, life shortening, sterility, radiation sickness, and the damaging effects on the molecular level resulting from exposure of the higher organ systems;

(*b*) Kinds and levels of injuries resulting from various types and quantities of radiation to provide data pertinent to the consideration of modifications in permissible exposure and concentration standards;

(*c*) Protecting the environment against radiation including studies of waste disposal methods, of shielding and of the kinds, volume and effects of fallout;

(*d*) Ecological studies of plant and animal life in the environs of atomic energy plants in order to contribute to man's knowledge of the patterns of animal and plant life under the impact of increasing levels of radiation in the biospher.

(*e*) Effects of ocean currents and related ocean phenomena on radioactive waste disposal at sea, including studies of marine biology, and industrial fisheries products;

(*f*) Genetics and radiation;

(*g*) Chemical and radiation toxicology of certain atomic energy products and compounds.

(*h*) Improved techniques and methods for detecting and measuring radiation.

LISTING OF PROJECTS UNDERWAY OR PROJECTED [6]

The scope of the Commission's research effort bearing upon present exposure standards and directly, or indirectly, related fields of interest can probably best be described by listing the program categories in which research projects are now underway or projected. This is done in Table 3 which also indicates the number of projects (470 in total) in each category. These projects are or will be carried out under contracts with other Government Agencies, colleges and universities, hospitals, private research institutions, industrial organizations and others.

[6] The research projects discussed here refer to the Off-Site Research Contracts administered by AEC's Division of Biology and Medicine.

TABLE 3.—*Current research projects bearing on present standards*

Program categories:	*Number of projects underway or projected*
Irradiation effects, molecular	121
Irradiation effects, organ systems	61
Skeletal system	12
Blood and blood forming organs	18
Eyes	5
Nervous system	6
Other organ systems	9
Endocrene system	11
Irradiation effects, whole body	26
Immunity	13
Performance	4
Life shortening	5
Embryological effects	3
General	1
Combatting irradiation injury	13
Environmental radiation	19
Atmospheric monitoring	7
Meteorology	6
Particle collection	6
Biophysics	5
Burns and blasts	2
Agricultural research	41
Animal physiology	8
Soil chemistry	6
Crop improvement	2
Plant physiology	25
Ecology	26
Climates	4
Soils and landscapes	4
Plants and animals	16
Biospheric monitoring	2
Marine Sciences	16
Oceanography	6
Marine biology	10
Genetics	46
Human	1
Mutation rates	11
Population	6
Other	28
Toxicology	17
Cancer	33
Teletherapy	8
Isotope treatment	11
Carcinogenesis	8
Diagnosis	6

TABLE 3.—*Current research projects bearing on present standards*—Continued

Program categories—Continued	Number of projects underway or projected
Radiation Detection and Measurement	19
Radiation physics	3
Detectors	6
Instrumentation elements and systems	2
Photoelectronics	8
Education, training, and information	12
Multiple-purpose projects	13

SECTION 4. ORIGIN AND NATURE OF INDUSTRIAL HAZARDS AND RADIATION INJURY

INTRODUCTION

The kinds of radiation of interest in this report are those which have sufficient energy in a single unit to ionize atoms with which they interact. These are frequently designated "ionizing radiations" to distinguish them from other radiations such as visible, ultraviolet and infrared light, radio waves, etc.

Ionizing radiations may be released from the nucleii of the atoms as the result of either fission or radioactive disintegration, or they may be produced by use of high voltage accelerators such as x-ray machines, cyclotrons, bevatrons, etc. In each case a fundamental characteristic of the radiation is that it consists of individual units or packets of energy, each carried by either a fast moving *particle* or by an *electromagnetic quantum.*

A *particle* emitted by an atom carries energy produced by changes within the atom in much the same way that a bullet fired from a gun carries energy generated within the cartridge. The quantity of energy given to a sub-atomic particle or the bullet, together with its mass, determines the velocity with which it is emitted.

The emitted particles of most common interest in connection with protection against radiation are designated alpha particles, beta particles, and neutrons.

ALPHA AND BETA PARTICLES

By virtue of their electric charges, alpha and beta particles moving through any kind of matter exert electrical forces which result in the ionization of a small fraction of the atoms or molecules along their paths. In this manner, the kinetic energy originally possessed by the particles is transferred to the material. The maximum depth to which a charged particle can penetrate a material depends upon its initial energy and upon the rate of loss of energy by ionization along its path.

The probability of a moving electric charge removing a nearby electron from atom or molecule with which it is associated depends upon the velocity with which the charge is moving. Both alpha and beta particles reach optimum velocities for ionization near the ends of their paths. However, because of their much greater masses, alpha particles have much lower velocities than beta particles of the same

energy. As a result, on the average alpha particles produce hundreds of times as many ions along their paths as do beta particles. Because of this rapid loss of energy, alpha particles can penetrate matter only to small depths, depending upon the density of the material. For example, the ranges of alpha particles in air are of the order to two or three inches, while in material of the density of human tissue, they are of the order of a couple of thousandths of an inch.

Depending upon their energies, individual beta particles emitted by radioactive materials may penetrate body tissues to depths ranging from very small values to more than an inch. However, the distribution of energies in beta particles emitted by any radioactive material is such that most of the particles lose their energy comparatively near the incident surface.

NEUTRONS

Neutrons carry no electrical charges and hence a neutron may travel comparatively long distances through matter before interaction. A long distance, as used here, may be several thousandths of an inch or many feet. The distance is long compared to that which a charged particle moves between ionizing events. Eventually, however, the neutron collides with the nucleus of an atom of the material with the result that it transfers to the atom sufficient energy to project it through the material as an ionizing particle. By a succession of such collisions, the velocity of the neutron is reduced to a range in which it can be captured by one of the atoms with which it collides. The usual result of such a capture is the emission, with relatively high energy, of a charged particle or of a quantum of gamma radiation.

THE GAMMA QUANTUM

The gamma quantum differs from the particles discussed above in that it always moves in empty space with the speed of light and has no separate existence except when it is transferring energy from one atom to another. Like the neutron, it carries no electric charge and hence may travel comparatively long distances through matter before collision. Eventually it collides with an electron, transferring sufficient energy to project the electron as an ionizing particle. Such an electron is, in all respects, identical with a beta particle.

INJURIOUS EFFECTS OF IONIZING RADIATION

Because of the fundamental difference in the mechanisms by which charged and uncharged particles produce ionization, alpha and beta particles of particular energies have definite maximum ranges in any particular material, while neutrons and gamma quanta do not. It is impossible to interpose in a beam of neutron or gamma radiation a wall of material sufficiently thick that none of the radiation will emerge from the opposite side. If a layer of the material is sufficiently thick that just half of the incident neutrons or quanta will pass through it without collision, half of the emerging beam would pass through another layer of the same thickness without collision, etc. Since those neutrons or quanta which have undergone one or more collisions have greater probability of collision than before, it is possible by making the wall sufficiently thick to reduce the number

passing through it to as small a value as may be desired. Thicknesses of shields required for radiation safely depend upon intensities of incident radiation (i. e., numbers of neutrons or quanta incident upon the shield), particle or quantum energies, materials of construction, and the intensity of emergent radiation which can be tolerated. In nuclear reactors and chemical processing plants, thicknesses of material equivalent to many feet of concrete may be required to reduce radiation to levels acceptable for more or less continuous exposure of personnel.

The average rates at which beams of neutrons or gamma quanta lose energy in passing through materials depends upon the energies of the individual neutrons or quanta. If the individual energies are low, such a beam incident upon the human body will lose most of its energy near the surface, while the loss from a beam in which individual energies are high will be more uniformly distributed through the body. Since the injurious effects of ionizing radiations increase with increases in absorption of energy, radiation injuries from low energy neutron or gamma radiation originating outside the body are largely confined to surface tissue while high energy gamma rays may injure tissues throughout the body.

For similar reasons, injuries from beta radiations originating outside the body are largely confined to the skin and tissues near the surface, while most of the energy of alpha particles is absorbed by the insensitive outer layers of the skin with no biological effects.

RADIOACTIVITY AND RADIOACTIVE MATERIALS

Many kinds of atoms appear to be absolutely stable; other kinds appear to possess inherent degrees of instability such that any one atom of a kind has a definite probability of undergoing a spontaneous change in its nuclear composition in a given period of time. Such a change is generally accomplished by the emission of an alpha particle or a beta particle from the nucleus, and is frequently accompanied by the emission of one or more gamma quanta. Atoms possessing this property of spontaneous nuclear change are said to be *radioactive*, and the change which the atom undergoes is called radioactive distintegration or transmutation. Decreases in radioactivity of a given material resulting from radioactive disintegration of its atoms is frequently called radioactive decay.

As a result of radioactivity involving the emission of a particle carrying an electric charge, the *chemical* properties of the atom are changed. For example, an atom of radioactive carbon (carbon 14, frequently written C^{14}) in disintegrating emits a beta particle to become a stable atom of nitrogen (N^{14}, not radioactive).

Radioactive distintegration also changes the *physical* properties of the atom. In the case of disintegration of radio-carbon mentioned above, the nucleus becomes *stable*. In other cases, the resultant atom may be unstable (radioactive), but the degree of instability is changed. For example, an atom of radium 226 in disintegration emits an alpha particle to become an atom of radon 222. Radon 222 is much more unstable than radium 226.

A common measure of the degree of instability is the length of time required for any large number of atoms to decay to one-half that number. This time is called the radioactive *half-life* of the kind of

atom. Returning to the above example, the radioactive half-life of radon 222 is 3.8 days, while that of radium 226 is 1600 years. Radioactive half-lives of interest in the field of nuclear energy vary from fractions of a second to millions of years.

QUANTITIES OF RADIOACTIVE MATERIAL

Since our primary interest in most radioactive materials stems entirely from their radioactive properties, it is natural to describe quantities of such materials in terms of their activity rather than in terms of mass or volume. By custom, radioactivity has come to be measured in units equal to the rate of disintegration of one gram of radium, 37,000,000,000 atoms per second. This unit of radioactivity is called the curie. Quantities of radioactivity of frequent interest range from millions of curies (megacuries) occurring in nuclear reactors down to small fractions of one millionth of a curie (one microcurie) used in research.

The mass of a particular kind of radioactive material corresponding to one curie of radioactivity may be very large or very small, depending upon the degree of instability of the material. The following table is illustrative.

Illustration of relationships between activity, half-life and mass

Kind of atom	Half-life	Grams per curie	Curies per gram
Radium 226	1,600 years	1	1
Uranium 238	4,500,000,000 years	3,000,000	0.000,000.3
Cesium 135	20,000 years	7.5	0.13
Iodine 131	8 days	0.000,008	120,000
Sodium 24	14.8 hours	0.000,000.6	1,600,000

RADIOACTIVE DECAY AND RADIOACTIVE EQUILIBRIUM

We are frequently interested in the time required for an initial quantity of radioactive material to decay to some particular fraction of that quantity. Reduction in activity is illustrated by the following table.

Elapsed time (half-lives)	0	1	2	3	3.33	4	6.7	10
Fraction of activity remaining	1	1/2	1/4	1/8	1/10	1/16	1/100	1/1,000

KINDS OF ATOMS, CHEMICAL ELEMENTS, AND ISOTOPES

Any two atoms with equal numbers of protons are atoms of the same chemical element. However, if the two atoms have different numbers of neutrons, they are said to be atoms of different *isotopes* of the chemical element. Examples are strontium 89 and strontium 90 discussed above. The nucleus of strontium 89 contains 38 protons and 51 neutrons, while that of strontium 90 contains 38 protons and 52 neutrons.

If the atoms of a particular isotope are radioactive, the isotope is frequently referred to as a *radioisotope;* otherwise it is a *stable isotope.* A radioisotope of an element is frequently referred to by use of a term such as radiostrontium. This term may refer indiscriminantly to any one or several of the radioisotopes of strontium.

RADIATION DOSE AND UNITS OF MEASUREMENT

For purposes of relating levels of radiation exposure to degrees of injury and of specifying safe levels of exposure, it is necessary to devise or define units of measurement which may be used to relate absorption of radiation by biological tissues to the biological effects of such absorption. Four different units commonly appear in recent literature. These are the *roentgen*, the *rad*, the *rep*, and the *rem*.

The roentgen measures the radiation dose of x-rays and gamma radiation at any point in terms of the energy absorbed per unit mass of *air* at that point. (This definition contains a technical inaccuracy, introduced for simplification of concept.) Quantitatively, one roentgen corresponds to the absorption of about *84* ergs of energy per gram of air. The corresponding absorption of energy by a gram of tissue placed at the same point may vary by a factor of from *1/2* to *2*, depending upon quantum energies and upon the chemical composition of the tissue. For muscle, one roentgen corresponds to about 93 ergs per gram, while for bone the absorption is generally much higher.

The rad measures the radiation dose in terms of the energy absorbed per unit mass in the *material of interest*. In radiation protection, the material of interest is usually human tissue. One rad is defined as 100 ergs per gram. As an example of the difference between the roentgen and the rad, for a particular quantum energy, a dose of one roentgen to muscle might be 0.93 rads and to bone, 1.4 rads. In interpreting standards of radiation protection, it is generally permissible to assume that a tissue dose of one rad is equivalent to a tissue dose of one roentgen.

The rep is defined as a radiation dose of 93 ergs per gram of tissue. Officially it is susperseded by the rad, and is mentioned here only because of its wide occurrence in literature older than 1954.

The roentgen, the rad, and the rep are all measures of physical dose (energy absorbed per unit mass). The rem represents an effort to express the biological effect of a radiation. The name originates as an abbreviation of "roentgen equivalent man." By definition, one rem of any radiation is the dose of that radiation required to produce the same effect in man as one roentgen of gamma radiation of the specified quantum energy. (Various investigators have used different effective quantum energies for this purpose. A frequently used value is 0.25 Mev (million electron volts).) As an example, on the basis of available information it is believed that the number of roentgens required to produce radiation cataracts of a given severity in the eye is about ten times the number of rads of neutron dosage. On this basis, for the production of cataracts, 0.1 rad of neutrons is 1 rem.

It should be observed that, since the units of radiation dose defined above are related, directly or indirectly, to the energy absorbed *per gram of tissue* without reference to the total quantity of tissue involved, a complete description of the radiation does to an individual requires a statement of the distribution of dose throughout the body. By definition, if the individual receives a uniform dose of 400 roentgens throughout the body, the dose to each portion of the body, no matter how small or how large, is also 400 roentgen. However, the total effect would be very different if he received a dose of 400 roentgens to only a limited portion of his body, such as a finger or a small area of skin. The first case might be fatal; the second of no consequence.

In expressing dose received, one commonly specifies *whole body exposure to penetrating radiation, whole body exposure to low energy radiation*, or otherwise indicates the portion of the body to which a particular number applies. Portions of the body of common interest, in distinction to the whole body, are the hands and forearms, feet and ankles, head and neck, limited portions of skin or tissue in contact with a highly radioactive particle, or any particular organ such as the eye, gonads, thyroid, skeleton, etc. (*Particle* is used here in a sense very different from that of its use in the terms, *alpha particle* or *beta particle*. Here we refer to a small speck or grain of material(s) containing a large number of radioactive atoms.)

PART II

STANDARDS, ADMINISTRATIVE REQUIREMENTS AND PROTECTIVE MEASURES—AEC CONTRACTOR ACTIVITIES

Introduction

Because of the variation in the nature of the hazards encountered from one installation to another, the Commission has established broad standards together with the necessary accompanying procedures and reporting requirements. Responsibility for the interpretation and administration of the standards and administrative requirements is assigned to Headquarters Division Directors. Managers of Operations are assigned similar responsibility as well as the responsibility for nsuring compliance. Technical interpretation of the standards is provided by the Commission's Division of Biology and Medicine.

The standards embody the recommendations of the National Committee on Radiation Protection and Measurement as published in handbooks by the National Bureau of Standards. The quantitative limits set in these recommendations are modified where necessary to make them applicable to conditions which arise out of activity over which the Commission is responsible. The National Committee's standards, when viewed quantitatively, are maximums. Contractors are free to set more conservative—i. e., more restrictive limits—subject to AEC approval, depending on local operating conditions.

The discussion of protective measures and instrumentation and monitoring included in this part is not intended as a comprehensive or detailed analysis of all methods and techniques used by contractors in their radiation protection programs. Only basic concepts are covered. A section of Part III, "Industrial Experience—AEC Contractors," is largely devoted to a discussion of methods and techniques employed by contractors in their radiation protection programs.

Section 1. Standards and Procedures

The Commission document containing the NCRP standards as revised on January 8, 1957, and discussed in Part I, Section 1, is AEC Manual Chapter 0524, "Permissible Levels of Radiation Exposure." Effective February 1, 1958, this Chapter establishes the rules governing AEC and AEC contractor personnel with respect to permissible levels of radiation exposure (exclusive of those engaged in weapons tests). The provisions apply also to others who may be exposed to

radiation from AEC operations. Manual chapter 0524 is included as appendix B–1.

The successful operation of the permissible level concept of radiation control necessarily entails a comprehensive system under which exposure must be recorded and employees notified of their exposure history.

Commission policy governing this is set forth in Chapter 0525, "Occupational Radiation Exposure Information for AEC and AEC Contractor Employees," (appendix B–2) published in May 1958. The provisions of this chapter embrace all AEC and AEC contractor employees plus contractor employees who may also be engaged in work performed under an AEC license. This distinction is made because AEC Manual issuances are not otherwise applicable to AEC licensees. In summary, the chapter provides for informing employees of their radiation history: (*a*) whenever they request it, allowing reasonable time for preparation of the information; and (*b*) within 30 days after the close of the calendar year if the permissible yearly exposure of whole body external radiation has been exceeded.

Immediate notification is required if an employee has received a recorded accumulated exposure exceeding any of the following limits specified in AEC Manual Chapter 0524: (*a*) in any calendar year or calendar year quarter, the yearly or quarterly permissible dose for external penetrating radiation to the whole body; (*b*) a quantity of any radioisotope (whose effective half-life is 180 days or greater) in the total body; or (*c*) a quantity of any radioisotope in the body resulting in a calculated dose in rads to any organ exceeding the yearly permissible dose for that organ.

Section 2. Protective Measures—Instrumentation and Monitoring

The methods used to protect personnel from harmful effects of radiation differ depending on the nature of the hazard. The unique penetrating characteristics of external radiation militate against the use of protective clothing or any of the devices normally utilized for protection against internal radiation. Therefore, a combination of three concepts—time, distance, and shielding—represents the conventional methods employed. Thus, protection against penetrating external radiation is afforded by: (1) Controlling the duration of exposure; (2) Controlling the distance between the man and the source of the radiation; and (3) Placing an absorbing material or shield between the man and the source of radiation. The application of these concepts in operating situations will be covered in part III.

The problem of protection against internal radiation hazards is considerably more difficult than that encountered with external radiation. Instruments are available to measure the amount of external exposure received or present at any given time. Internal exposure, however, involves the deposition of radioactive particles into the body. The effect of this deposition varies with the nature of the material. Also, an individual's particular physiological makeup will, in a sense, affect the degree to which a particular substance inflicts damage.

Because internal radiation exposure results from the introduction of radioactive substances into the body, the protective measures used seek to prevent this from happening. Since these measures will be

illustrated in part III as they are utilized operationally by contractors, they will be treated only generally here.

Radioactive airborne particles constitute one of the greatest hazards. Most techniques, designed to insure against this hazard, attempt to confine and contain the materials so as to prevent their becoming airborne. Thus, materials are handled in closed systems; vacuum cleaners, connected to a permanent system, are used to pick up dust; ventilating systems provide air flow in the proper direction; etc. Where employees are unavoidably exposed to airborne concentrations such respiratory protection as the following can be used: the simple filter-type respirator; the filter-type gas mask; a self-contained type of gas mask equipment; or a completely enclosed plastic suit with an independent air supply.

Non-airborne materials may be protected against, in some cases, by simple hygienic habits, such as washing the hands before eating. Other situations may call for measures such as showering before leaving the area, and wearing protective clothing while at work in a contaminated area.

The effectiveness of protective and control practices can be measured by certain monitoring techniques using a variety of instruments designed for specific purposes. Each person working near radiation sources, or who may reasonably expect to be near a source of radiation, normally wears a film badge or dosimeter. These measure the amount of beta or gamma radiation present in the immediate environment. Film badges are developed and the amount of exposure determined by comparing the film against film which has been previously exposed to known quantities of radiation. The film badge gives a permanent record of exposure. However, it is not capable of instant reading as is a dosimeter.

More precise instruments are used by health physicists in the monitoring of areas and personnel such as the Geiger-Müller Counter—the most widely known of these instruments. The GM (Geiger) and the scintillation counter are effective for measuring low level rates of radiation; the ionization chamber for measuring higher levels of beta and gamma radiation.

The instruments and techniques for measuring the amount of internal exposure are not as satisfactory as for external radiation. Whole body counters will measure the total body content of energetic gamma emitting compounds at levels considerably lower than permissible, but will not measure the body content of beta and alpha emitting material. This content must be inferred by measurements of excreted body wastes—the so-called bio-assay techniques. These include such tests as anlysis of expired air samples, urinalysis, and blood and bone-marrow analysis.

Section 3. Reports

In order to evaluate the effectiveness of the Commission's overall Radiation Protection Program, information on personnel exposures are submitted to Headquarters on a systematic basis. The procedures governing this reporting system are contained in Manual Chapter 0523—"Radiation Exposure Reports"—which appears as appendix B–3. The requirements of the chapter extend to all activities under the Commission's direct jurisdiction. They do not apply to licensee

facilities. Reports submitted are of two kinds—Annual and Special Reports. The Annual Report summarizes statistically external and internal exposure of AEC and contractor personnel broken down by number of personnel in exposure range increments running from 0—1 rem to the final range of greater than 15 rem. Additional information is also submitted such as: number of personnel for whom monitoring is *not* required, and methods used to estimate rem dose if conventional methods are not used.

Special Reports are required *immediately*, by telephone or teletype, if one of the following occurs: (1) an individual receives an external radiation dose greater than 15 rem; (2) an internal body deposition is received which is greater than the permissible concentrations as specified in chapter 0524; (3) a member of the general population is believed to have received a radiation dose in excess of that specified as the permissible dose in chapter 0524.

AEC Manual Chapter 0502, "Injury, Fire and Property Damage—Records, Reports, and Investigations" (appendix B–4), published in 1955 and revised in October 1958, also requires the reporting of an "injury or industrial illness following cumulative or massive exposure to internal or external ionizing radiation which might reasonably be expected to have caused the illness or injury and when so diagnosed by a physician competent in nuclear medicine."

The reporting of injury or illness is handled like the Special Reports discussed above in that immediate notification is required, followed by an investigation and subsequent report.

Each contractor—or each Operations Office Manager in the case of direct Federal activities—is charged by the Commission with the responsibility for taking all necessary and reasonable measures to protect employees and the public against the hazards of radiation. Through a continuing program of hazards evaluations, periodic and special reporting, on-the-spot investigation of incidents, safety engineering, routine and non-routine inspections, etc., the Commission keeps constant surveillance over the health-physics, safety and related programs carried on at all facilities under its direct jurisdiction.

PART III

INDUSTRIAL EXPERIENCE—AEC CONTRACTORS [7]

Introduction

The development of the radiation standards was discussed in part I. Part II was devoted to an explanation of how the AEC has adopted these standards for its own and its contractor operations. Part III serves to illustrate the methods by which AEC contractors control radiation exposure and deal with radiation hazards.

[7] For a discussion of industry experience outside the AEC area of control see "Radiation Protection in the Industrial Use of Radiation" by W. A. McAdams of the General Electric Co. This paper was presented at the Second United Nations International Conference on the Peaceful Uses of Atomic Energy.

Section 1 is a summary of methods and principles employed by contractors to enable them to operate within maximum permissible limits of radiation exposure. Also included in this section is a presentation of the nature and extent of restrictions placed on employees who have been exposed to more radiation than permitted under applicable working limits.

Sections 2, 3, and 4 are devoted to a closer look at radiation protection programs in major areas of Commission activity.

Section 2 was prepared by the General Electric Co., the Commission's contractor for operating the production facilities at Hanford.

Section 3 was submitted by Brookhaven National Laboratory, operated by Associated Universities Incorporated under an AEC contract administered by the New York Operations Office.

Section 4 was prepared by the Phillips Petroleum Co., Atomic Energy Division, the prime contractor for research and development activities carried on by the Idaho Operations Office of the Commission.

Section 1. Controlling Radiation Exposure

INTRODUCTION

The control of radiation exposure to personnel has necessarily been an integral part of contractor activity since the beginning of the atomic energy program. With the passage of time, the exchange of accumulated experience between AEC and its contractors and among contractors has resulted in the development and application of increasingly more refined methods and procedures not only in the control of personnel exposures but also in the detection and measurement of radiation.

As indicated above, the AEC has incorporated in its own standards the recommendations, as they have been revised from time to time, of the National Committee on Radiation Protection and Measurement. These recommendations have also been adopted in Handbooks published by the National Bureau of Standards. The historical development of the standards and their underlying philosophy are discussed in part I, section 2.

One of the inevitable consequences of any control system which sets arbitrary limits by time periods on the amount of radiation exposure an individual may receive is the necessity, occassionally, for imposing work restrictions on employees who have exceeded or are approaching established exposure limits. Of natural concern to employees and employers alike is what happens to workers who may be placed on such work restrictions.

A recent study has been made of the various ways AEC contractors have been dealing with this problem. Four major areas were reviewed: the methods and principles employed by contractors to enable them to operate within AEC requirements; the type of employees who have been subjected to restrictions; the duration of work restrictions; and the employment arrangements made for employees under work restrictions.

METHODS AND PRINCIPLES

The standards established in AEC Manual Chapter 0524 set the levels of radiation exposure which are the maximum permissible occupational exposures for AEC and contractor employees. In line with the desirable objective of keeping exposures to a practical and feasible minimum, contractors are free to establish more conservative or restrictive levels, subject to the approval of Managers of Operations.

The contractors who have established more restrictive requirements have generally followed a policy of reducing the amount of exposure an individual can receive in weekly or quarterly time periods. Previous NCRP and AEC standards subscribed to weekly controls. This method of control has recently been rescinded by the NCRP. The AEC adopted this recommendation. For example, earlier rules set the maximum permissible level at .3 rem/week, 3 rem/quarter and 15 rem/year for whole body radiation. Present AEC standards no longer prescribe a weekly maximum but rather state only that "* * * the maximum permissible accumulated dosage in rems at any age, is equal to 5 times the number of years beyond age 18, provided no annual increment exceeds 15 rems." and that "* * * not more than one-fourth of the 15 rem maximum permissible yearly dose shall be taken in one-fourth of a year."

Contractors' more restrictive standards generally take two forms: (1) adherence to current AEC requirements (i.e. use of the quarterly and yearly time periods only) with less than prescribed amounts of exposure as maximums or; (2) the use of the former weekly maximum in addition to the quarterly and yearly control limits.

The methods followed by contractors to keep exposure below the levels established—either those of the Commission or their own, more restrictive standards—vary from contractor to contractor. The most predominant, however, is the work permit system. By this method, individuals cannot work in areas where radiation levels exceed certain values except by means of a work permit which allows an employee to enter and remain in the area for a certain length of time.

The principles governing the application of the standards can best be described as dose control. In this sense, individuals who, in the normal course of their employment, are exposed to various amounts of radiation, have their exposure controlled by health physicists, aided by the monitoring techniques and protective devices suited to the hazard encountered. The controls are designed to assure that an employee never receives a dose, or is exposed at a rate which will exceed the standards. But, as in other activities, accidents happen in atomic energy. As a result, individuals have been exposed to more radiation than the established working standard for a given period. When this occurs, the exposed employee is usually removed from work involving radiation for period of time—the duration depending on the nature and severity of the exposure.

So long as the working standards are not exceeded, their administration is almost exclusively by health physicists applying administrative criteria. When accidents occur, however, medical personnel are usually called in. They evaluate the possible effect of the exposure, determine the physical condition of the employee and, in conjunction

with health physicists and management, decide the duration of the work restriction. The final determination of when an individual may return to work is generally made by the medical staff taking into account the 5(n–18) formula discussed in part I, section 2.

It should not be inferred from the foregoing that two sets of standards are in effect at AEC installations. The more restrictive limits used by some contractors are only "working limits" within the *mandatory maximums* established by AEC.

It was pointed out in part I, section 2, that the concept of average yearly dose—or for that matter, the entire "maximum permissible" concept—is somewhat arbitrary; at least it is as much administratively oriented as it is scientifically based. This is so in large part because at some point in the field of radiation protection, scientific data is inconclusive and sound judgment must be used concurrently with the scientific information at hand.

It has been mentioned earlier in this report that there is room for reasonableness in discussing present standards. For administrative purposes, however, some fixed levels must be used even though it cannot be firmly established that slight amounts of exposure beyond these levels will cause damage.

Management has recognized that in some situations the multiple objectives of maintaining the minimum feasible exposure and keeping within the maximum permissible limits can most effectively be met by the use of working standards *below* the AEC prescribed maximums.

In our recent review of Work Restriction practices reports were received on a total of 739 restrictions involving 718 employees (eleven employees were restricted twice each, and three restrictions were imposed on each of 5 employees). The coverage is believed to be representative in terms of types and duration of restrictions and reasonably comprehensive as to number for a 21 month period.

Very few of the restrictions cited were imposed as a result of accidental exposure above Commission established limits. The great majority of employees restricted were so treated because: (1) an exposure had been received which may have been *below* the Commission's maximum levels, although in excess of the contractor's working standards; (2) employees were receiving exposures at a rate which would have *approached*, if allowed to continue, the maximum permissible dose (prescribed by the Commission or set by the contractor) before the authorized time period had elapsed for that amount, or; (3) in controlling the worker's exposure, measures were taken to prevent the *possibility* of these latter two situations from happening. The extent to which any of these reasons may have been used in imposing restrictions is not known. It can be inferred, however, that since the large percentage (78 percent) were less than one month, the practice of preventive rather than corrective restrictions prevail.

TYPE OF EMPLOYEE RESTRICTED—DURATION OF RESTRICTION

Table 4 below divides the work restrictions into eight time groups ranging from less than one month to more than 24 months.

TABLE 4.—*Work restrictions imposed by AEC contractors, Jan. 1, 1957–Sept. 30, 1958 (43 contractors, 52 installations)*

Number of employees restricted:	
Hourly manual	469
Scientific technical	189
Other	60
Total	718
Duration of restrictions (months): [1]	
<1	580
1–3	69
3–6	31
6–9	21
9–12	3
12–18	1
18–24	5
>24	29
Total	739

[1] 11 employees, 2 restrictions each; 5 employees, 3 restrictions each.

The 29 restrictions in excess of 24 months are of the following duration:

From 27–30 months	4
37 months	1
39 months	1
41 months	1
46 months	1
49 months	1
60 months	2
63 months	2
92 months	1
108 months	1
Permanently reassigned	13
Exact length of restriction not yet determined	1

From an employee relations standpoint, one of the most important aspects of the problem of controlling radiation exposure by work restrictions is the employment arrangement made for the period of the restriction.

The largest number of workers restricted (474 out of 718) were allowed to remain on their present jobs, with more rigid limitations than would normally apply being placed on the amount of radiation they could receive.

The second largest number (230) were temporarily detailed to other jobs not involving exposure to radiation. The remaining 35 restrictions involved permanent reassignments to other positions in the same establishment where there would be little or no chance of future exposures. These 35 are made up of the 13 shown above as permanently reassigned from the >24 months group plus 22 others reported as restricted for shorter periods of time—but with respect to whom a decision in favor of permanent reassignment was made during the shorter restriction.

It is worthwhile noting that no employee was separated from the payroll as a result of overexposure (although two employees placed on work restrictions were terminated for other reasons during the period of their work restrictions); no employees were displaced as a result of permanent reassignments; and in only one case was an employee's earnings affected as a result of the imposition of a work restriction.

In this instance the employee had been receiving a "premium area allowance," over and above his base rate. This was no longer applicable after his reassignment however, his base rate was not affected.

SECTION 2. PRODUCTION FACILITY—HANFORD ATOMIC PRODUCTS OPERATION, GENERAL ELECTRIC CO., RICHLAND, WASH.

METHODS USED IN APPLYING STANDARDS

Hanford radiation protection standards are based on a number of written expressions of policy, issued as a manual (HW–25457 REV 1). One of Hanford's principles is the maintenance of radiological working conditions such that there are no radiation injuries to workers, and that individual accumulated exposures are controlled to within established exposure limits. In addition, it is Hanford policy to minimize exposure of employees to ionizing radiation and to limit exposures to within values presently considered acceptable by the National Committee on Radiation Protection and Measurements and to AEC directives for which HAPO has contractual obligations.

These standards apply to all employees engaged in production, research, service, and construction activities. All Government employees and visitors associated with Hanford activities also come under the same radiation control requirements. The standards are implemented by detailed procedures and work practice manuals written by each organizational component performing work with ionizing radiation. All of the procedures are directed toward keeping exposures to people at the lowest practicable level.

Controlling exposure

Although the personnel meter program is established such that a record of each individual's exposure is created, through the issuance of film badges to each person with access to production areas, the actual number of people requiring close exposure control is relatively small.

The overall control of whole body exposure to *penetrating types of radiation* (X- or gamma, neutrons) is mostly achieved by the use of shielding with concrete walls, lead bricks, etc., such that in routinely occupied work areas, the dose rate is less than 0.001 rad/hour.

In addition, control is achieved through the use of distance, utilizing remotely operated crane, hoists, tools, etc., or sometimes utilizing water in a pool to serve as a means of distance, shielding, visibility and contamination control. Lastly, personnel exposure control is achieved by utilizing time. One use of time is to allow short-lived radioisotopes to decay, another is to limit the time a worker can stay at a job by determining the dose rate and then limiting his time in the work area to insure that the permissible dose will not be exceeded.

The control of *internal exposure* to within permissible limits has been accomplished by the use of physical contamination barriers, both inclusion barriers such as walls and plexiglass or plastic bags, and exclusion barriers such as protective clothing and respiratory equipment. In support of controlling personnel internal exposure, building designs have incorporated ventilation systems and air locks such that any airborne contamination that escapes an inclusion barrier will tend to be localized and confined to the immediate vicinity.

Personnel protection measures

Although Hanford in size is over 640 square miles, less than a few square miles in total are designated as radiation zones, or locations wherein the potential for significant quantities of ionizing radiation may be encountered.

All Hanford radiation zones are positively identified and isolated by barricades, signs, occasionally flashing lights, locked gates or doors, etc. In addition, in locations where the dose rates are extremely high or may be expected to fluctuate widely or are unknown, more rigid personnel protection measures are used such as interlocking doors, entry and exit logs, and lock and tag procedures.

Administrative controls for personnel protection consist of requiring written and countersigned work procedures for each radiation zone entry which describe the work location, limit the work to be performed to specific tasks, prescribe protective apparel as appropriate, and specify radiation monitoring controls.

Additional personnel protection measures are:

(*a*) Detailed work planning sessions for any major or nonroutine radiation zone work.

(*b*) Staff radiation protection services which not only provide detailed and continuous evaluation of radiological working conditions but also consultation on techniques and procedures directed toward minimizing human exposures.

(*c*) Worker education programs ranging from on-the-job instructions through graduate level seminars and lectures.

(*d*) Active and separate conventional safety programs, including formal joint management-labor inspection committees. These programs actively pursue conventional working conditions such as lighting, sidewalks, sanitary facilities, transportation, fire and electrical protection, etc., which can have a concomitant influence on the effectiveness of the Hanford radiation protection program.

(*e*) Company-issued protective apparel such as coveralls, rubbers, masks, etc.

(*f*) Periodic medical examinations and consultation with industrial physicians whenever requested.

Instrumentation and monitoring

External exposure of employees to ionizing radiation is measured and controlled through the use of individually issued film badges. The badge utilizes photographic film and suitable filters, and provides for individual and definitive monitoring of the external exposure of every employee with access to production and laboratory areas, regardless of entry into radiation zones. Other devices such as pocket dosimeters (pencils) and finger rings are occasionally used where specified.

Evaluation of any internal deposition of radioactive materials in employees is achieved through the bioassay program. This program provides for periodic sensitive analyses of body fluids, primarily urine, and subsequent evaluation of the magnitude of internal deposition. Under current construction is a whole body counter facility which will permit external direct measurement of internally deposited radioisotopes through the use of extremely sensitive gamma-detecting instruments housed in a massively shielded room.

Semiautomatic hand and shoe contamination detectors are also provided throughout the work areas to permit frequent checks by each person upon his exit from radiation zones known to contain significant quantities of radiation contamination. These instruments supplement check stations established at principal work locations within radiation zones and which are used to promptly detect any evidence of contamination on protective apparel.

Work location monitoring is achieved in three ways. First, by a plantwide system of health monitor (HM) chambers sensitive to gamma radiation and operating in over 100 different key work locations, both inside and outside of radiation zones. The second basic form of work location monitoring is an integrated net work of air-sampling stations which, after processing the air samples, provide a means for evaluating the radiological status of the breathing atmosphere. The third means is through the use of portable survey instruments, which in the hands of trained users provide an instantaneous means for determining the dose rate and/or level of contamination.

Employee training in radiation protection instrumentation and monitoring is a continuing program. New employees are instructed in the proper wearing of personnel meters and use of hand counters. Experienced employees, who are engaged in radiation work are instructed in the use of simplified survey instruments. These training programs are evidence of Hanford's belief that the radiation worker, for his own self-protection, must be able to understand and use provided protective devices.

Recording exposure

The radiation sensitive film, after removal from the film badge and processing, is the Hanford primary exposure record. For the rare occasions when this film badge is lost or damaged, an investigation is conducted and the person's exposure is reconstructed and documented by extrapolating from fellow workers' exposure, or HM chamber readings, as the chamber response is continuously recorded and permanently maintained.

Records are also created and kept of each evaluation of internal deposition which is made, as are the records of any person's involvement in a radiation incident whether or not any exposure exceeded permissible limits.

The film badge records, internal deposition records, and pertinent incident records are maintained as strictly private individual exposure history dossiers and are kept indefinitely in fire-resistant storage vaults.

The radiation surveys written by monitoring personnel in the course of evaluating the radiological status of work locations and specific jobs are also permanently filed.

All routine personnel exposure history information is processed by electronic data processing systems. This enables centralized, detailed, and diverse statistics to be promptly supplied to management and enables the worker's exposure to be always currently available, a distinct advantage to Hanford because there are over 12 principal work locations widely separated over the 640 square miles that make up the project.

EVALUATION OF HANFORD CONTROL METHODS AND STANDARDS

Conventional safety at Hanford benefits from the extensive radiation protection program. Thus, safety statistics reflect the intangible benefits from the skill, care, and effort applied in radiation zone work.

Hanford safety summary, 1944–58

Man-hours worked	million	235. 5
Disabling injuries	total	149
Average injury frequency	per million man-hours	0. 63
AEC contractors all-time low		1. 68
All industry, 1957		6. 27
Accidental deaths—all causes		3
Injuries attributable to radiation		[1] None
Deaths attributable to radiation		None

[1] EDITOR'S NOTE.—Although there were no clinically observable injuries attributable to radiation, the 1 Hanford employee cited on table 5, p. 119, was reimbursed by the employer for 4 days away from work while under medical observation.

Controlling exposure

The exposure of employees to external penetrating radiation has been controlled to levels well below permissible limits recommended by the NCRP. The *ten* employees at Hanford who have received the *highest* cumulative exposure have received an average total dose of 17 rem. This is less than one-seventh of the average cumulative dose these ten employees could have received and still have been below the permissible dose allowed under the 1958 NCRP recommendations.

Since 1944, there have been over 18,000 different people who have worked or are working at Hanford. Of this number, only 14 employees have a body burden of radioactive materials which exceed one-fifth of the NCRP recommended maximum permissible limit (MPL) for occupationally received internal deposition. Of these 14, three exceed NCRP permissible limits. No Hanford employee has shown any demonstrable effects from deposition of radioactive materials.

Nominal radiological work restrictions have been made on an administrative basis for Hanford employees. All radiological work restrictions have been as a result of internal deposition of radioisotopes and with but minor exceptions these have all been plutonium. Employees with one-fifth or more of the plutonium MPL are assigned to work in which the likelihood for further plutonium exposure is minimal. Employees who have a body burden at or in excess of the MPL for plutonium (0.04 μc $Plutonium^{239}$) are restricted from further radiation work. No radiological work restrictions have been necessary because of whole-body external exposure received at Hanford.

Personnel protection measures

Hanford personnel protection measures are broadly grouped into physical confinement or control of radiation sources and administrative procedures. Physical control has been such that no significant exposure of employees has resulted from insufficient identification or barricading of these radiation work zones. Administrative measures, including extensive training of employees, have provided the development of extensive procedures and methods for performing radiation work. These have contributed to the achievement of minimizing radiation exposure to employees as discussed above.

Protective clothing is worn to avoid skin contamination or contamination of personal clothing. In 1957, approximately a half-million

coveralls and other items of protective apparel were worn by Hanford employees. Employee reimbursement for personal clothing inadvertently contaminated and confiscated in 1957 was less than $400 and involved less than 50 different items of clothing. None of these constituted a hazard but were retained as a matter of policy because they could not be decontaminated successfully to below detectable levels.

Approximately 1,000 cases of skin contamination occurred in 1957. The majority of these involved insignificant amounts of radioactive material. None of these cases resulted in localized external exposure to the skin or internal deposition of any concern. All cases of skin contamination at Hanford have been successfully decontaminated.

Instrumentation and monitoring

Instrumentation and monitoring are cornerstones in a comprehensive radiation protection program. In Hanford's experience no failures in instrumentation or faulty monitoring techniques or services have caused exposure of employees to radiation doses of any concern.

Hanford's film badge and bioassay programs have sufficient quality to measure the individual radiation dose an employee may receive down to levels substantially below maximum permissible exposure limits recommended by the NCRP.

Recording exposure

Exposure records and certain other key records, such as signed radiation surveys and charts recording work location radiation measurements, are permanently stored. Although the need for these stored records has been very infrequent, they serve the function of being able to reconstruct the radiological status of work location and situations.

The recording of routine exposure data through the use of electronic data processing machines has made practicable the annual reporting to each employee of his recorded accumulated whole body exposure in the form of a strictly private, radiation report card. This extension of communications has been well received by employees.

Section 3. National Laboratory—Brookhaven National Laboratory, Associated Universities, Inc., Upton, Long Island, N.Y.

INTRODUCTION

The problem of radiation safety at a large AEC supported research laboratory is similar to that at other types of installations in that similar radiations and biological effects are involved and the basic techniques available for protection are similar. However, there are numerous differences, among which we might mention the following: (1) The technical activities are very varied and are constantly changing so that rigid standardization of procedures is not feasible. (2) It is necessary to retain a high degree of flexibility so that diverse and original experiments may be carried out. (3) There are many visitors and relatively transient personnel as well as many very competent research scientists who require radiation safety services and supervision. Thus, training programs and a high caliber of Health Physics personnel are especially important.

This particular laboratory encompasses most of the radiation safety problems encountered by research laboratories in general. However, the following are of major interest: (1) Radiation safety for a number of high-voltage accelerators, including a 60" cyclotron and the 3-Bev. cosmotron. (2) Exposure and contamination control in operating and using the large-air-cooled research reactor. (3) Waste disposal in an area where minimal use may be made of the ground for disposal of liquid or solid radioactive wastes.

This discussion will be divided into three parts: first, a brief outline of the control methods and standards utilized; second, a discussion of certain special problems in radiation safety that are particularly prominent at this laboratory; and third, some overall evaluation of the control methods and standards as actually applied under operating conditions.

METHODS OF RADIATION PROTECTION

Radiation protection starts with proper design of facilities. The primary responsibility for this matter lies with the scientific group that specifies the nature of a new facility and with the architects and engineers who do the detailed design. The Health Physics Division participates to some extent in the early planning and reviews the detailed design.

Measurement of radiation in laboratories and in the vicinity of accelerators and reactors is, perhaps, the primary protective technique. A variety of instruments, suitable arrangements for calibrating them and trained personnel for making and interpreting measurements, are required. The professional Health Physicists at this laboratory have Bachelors or Masters degrees, plus specific training in Health Physics. The technicians, or technical specialists, have junior college education. This high level of technical competence has been set up with two objectives in mind: first, to cope with the extremely varied problems encountered at a laboratory of this type, and second, so that a certain amount of research and development can be carried on by the Health Physics staff concurrently with their service activities.

Radiation conditions in the surrounding areas are monitored by means of several fixed stations containing automatic equipment. Daily samples of the laboratory's liquid waste effluent are analyzed for gross activity. Routine measurements of gross fallout activity from weapons tests are carried out. This "area monitoring" aspect of the program is relatively small since the gaseous and liquid waste effluents from this laboratory have been shown to be far below the officially designated safe limits.

Personnel monitoring by means of film dosimeters is provided for all individuals in areas where measurable exposures may be encountered. A Remington Rand punchcard system is utilized for recording quarterly and annual exposures and for computing integrated exposures. Because of the very considerable neutron hazards associated with the high-voltage accelerators, nuclear track film (NTA) is included in all badges.

Other protective techniques that do not need to be explained in detail, are the provision of shielding where necessary, the use of remote handling equipment, the use of adequate hoods and ventilation systems, the provision of a variety of respiratory protection and protec-

34434—59——4

tive clothing, the use of work orders prepared by Health Physicists for maintenance work, etc.

This laboratory has relatively few problems involving pure alpha emitters but maintains a special facility in a portion of the Hot Laboratory where work of this nature is carried out. There is also a facility for critical experiments that is carefully segregated from the rest of the laboratory and whose operation involves a relatively small number of people.

A program of urinalysis for gross activity and, in some cases for specific isotopes (principally strontium), is carried out. This is a relatively small program involving one Chemist and one chemistry technician. Periodic surveys are made of certain groups whose work makes it possible that they may become internally contaminated.

The Health Physics Division operates a system of indoctrination lectures and interviews for new personnel and conducts training programs and refresher programs for individuals and groups throughout the laboratory as required. Since the General Safety program is administratively and operationally integrated with the Health Physics activities, general safety indoctrination and training are carried out concurrently.

STANDARDS

The extensive program of radiation protection just outlined is necessary so that both external and internal radiation exposures may be kept below safe upper limits. The standards followed in this connection are those issued by the National Committee on Radiation Protection and published in a series of U.S. Bureau of Standards Handbooks.

Locally applied standards in regard to the control of airborne and surface contamination are generally far more stringent than would be required for health reasons. This is because low and known background levels are frequently required in connection with the experiments that are in progress. Thus, most experimental areas may be entered by visitors without special protective clothing. This is not true of certain high level areas, the pile building during shutdowns or facilities used for special experiments.

Detailed standards and procedures in regard to all aspects of radiation safety are published in the BNL Safety Manual for the guidance of all concerned. In addition to provisions for exposure and contamination control, the manual contains sections on personnel monitoring, the use of the Health Physics Instruction Sheet, waste disposal, laundry procedures, Fire Department procedures and emergency coverage.

ACCELERATOR SAFETY

Safety problems related to particle accelerators loom large at BNL since the laboratory operates two cyclotrons, the 3-Bev. Cosmotron and several Van de Graaf generators. The hazards associated with these machines are very considerable and a great deal of effort has been expended to achieve safe operating conditions. The 60″ Cyclotron and the Cosmotron pose the major current problems, but the 30-Bev. machine (alternating gradient synchrotron) now under construction will result in additional problems in the not-too-distant future

THE 60'' CYCLOTRON

The 60'' Cyclotron itself is located in a vault not normally entered during operation of this machine. Experience has indicated the need for rigidly fixing responsibility for evacuation of the vault prior to operation of the machine. This has been accomplished by the use of a recording lock mechanism at the console with numbered keys assigned only to a limited number of trained operators. The vault doors are equipped with the usual interlocks and both gamma and neutron radiation levels are remotely indicated by suitably located monitors.

A hot chemistry laboratory is provided adjacent to the cyclotron vault for processing of irradiated targets. This is provided with hoods, shielded work areas, storage facilities and decontamination and monitoring arrangements.

Also adjacent to the cyclotron is an experimental vault into which beams of particles may be projected. Here frequent access to the equipment is necessary and there are a variety of safety measures, including photoelectric barriers at the entrance, a closed circuit television monitor providing the cyclotron operator with a view of the area and radiation monitors for both neutrons and gamma rays.

THE COSMOTRON

The Cosmotron has been a difficult machine to use safely for a variety of reasons of which the following may be cited: (1) The initial design provided only partial shielding so that there have been large areas, necessarily frequented by experimenters, with appreciable radiation levels. (2) The output of the machine has increased 100-fold or more, since the initial period of operation, due to technical improvements. (3) The Cosmotron is used in many ways with different targets, intensities and geometrical arrangements. The resulting radiation exposure conditions are correspondingly diverse. (4) Radiation pulses occur only every five seconds, making conventional ratemeter types of instruments inapplicable. (5) Intense external beams of 3-Bev. protons may be brought out through the shield for experimental purposes and projected into a large outdoor area.

Despite the above difficulties, it has been possible to operate the Cosmotron safely with a minimum of restrictions on its use. To accomplish this, advantage has been taken of the fact that, for many experiments, operation at lower intensities is adequate. In addition, experimenters will usually spend only a fraction of their workweek taking data at the machine. Thus, exposures have been held well below maximum permissible values despite the existence at times of very high radiation levels throughout a major portion of the experimental areas adjacent to the machine.

Because of the low repetition rate of the pulsed radiation, it has been necessary to develop new monitoring instruments and techniques. Personnel monitoring by means of nuclear track films is an essential feature of the exposure control since the radiation levels vary considerably from place to place. In the absence of complete knowledge of the characteristics of the radiations encountered, safely conservative policies in regard to permissible exposure levels have been established. The external beam area has been fenced off and a large earthen dike

constructed to catch the external beam and prevent undesirably high radiation levels beyond the controlled area.

The Cosmotron has been shut down for some time for major repairs and alterations. The machine proper is being provided with complete shielding and a greatly enlarged indoor experimental area is being provided. When the experimental program resumes later this winter, greatly improved conditions are anticipated. However, the number and variety of experiments will increase as will the use of intense external beams. The Health Physicists assigned to this area will thoroughly evaluate the radiation exposure conditions and continue with their study of the detailed composition of the radiations encountered for various conditions of operation.

THE RESEARCH REACTOR

Brookhaven operates a large air-cooled research reactor that supports a very numerous and diverse array of scientific projects. One of the major exposure control problems encountered is associated with discharging of spent fuel elements and the manipulation of those fuel elements in the associated canal. As a result of occasional fuel element ruptures, everything coming from the pile has until recently been exceptionally contaminated. Now that the original fuel elements have been replaced with an improved type, this difficulty has been decreased. However, the new loading produces a much higher neutron flux and the induced activity of objects that have been in the pile is correspondingly higher.

Removal of very radioactive equipment from experimental holes in the pile and transportation of such equipment to other experimental areas or to the waste area are operations requiring careful planning and execution if the spread of contamination or high exposures are to be avoided. Numerous small objects and experimental samples are irradiated in the pile for varying periods of time and the removal and handling of such items, particularly while the reactor is operating, are also potential sources of exposure.

The Health Physics Division maintains a staff of six at the reactor with the necessary facilities for monitoring, assaying samples of air and surface contamination and for checking and removal of personnel contamination. Automatic alarms are provided to warn of abnormal gamma radiation levels or of appreciable airborne contamination and the release of radioactive materials from the reactor stack is also monitored.

WASTE DISPOSAL

Gaseous waste disposal is a minor problem at Brookhaven. The cooling air from the reactor contains large quantities of Argon-41 but is released from a 300-foot stack and diluted to a point well below maximum permissible at ground level. Off-gases from the hot laboratory are released from the same stack after passing through a caustic scrubber and filter. However, fuel elements are not processed in any quantity and hence gases from the hot laboratory pose no problem.

Liquid wastes are segregated at the source and only very low levels, totalling no more than 1.5 curies per year, are released to the labora-

tory sewage system and the small stream into which its discharges. Other liquid wastes are concentrated by evaporation and used to make concrete which is packaged in 55-gallon drums and disposed of in deep water beyond the edge of the Continental Shelf.

Solid wastes of very low radioactivity are discharged to the laboratory dump, the quantities disposable in this fashion being a maximum of 10 curies per year for short-lived materials and lesser amounts for materials with longer half-lives. Higher level solid wastes are packaged in 55-gallon drums for sea disposal where possible. When too active or not manageable physically for this type of disposal, solids are stored under ground in concrete-lined trenches or wells. Burial of intermediate or high level wastes on the Brookhaven site is not, at present, considered advisable because of the use of ground water for drinking and irrigation in nearby areas. Because of this situation, sea disposal is an attractive method and it is anticipated that arrangements will be made to dispose of larger concrete-loaded objects in the future.

EVALUATION OF CONTROL METHODS AND STANDARDS

In applying the exposure standards mentioned above, it is felt that they should be treated as valid engineering guides and that exposures approaching the stipulated maxima should be made use of where genuinely necessary. However, exposures over the limits should be assiduously avoided and, in particular, steps should be taken to assure that the limit on integrated exposures is not exceeded. It is the intention of the laboratory to prevent overexposures while avoiding costly and unnecessary over-protection.

Thus far the Brookhaven record on both internal and external exposures has been excellent with no case of exposure appreciably over the prescribed quarterly limit and with no case of an internal body burden comparable with the maximum permissible value. In no case has the limit on integrated exposure been exceeded. It is proper to point out that this is almost certainly partly good luck since the potential for serious exposure incidents exists in numerous locations. The chance of radiation accidents cannot be completely eliminated without intolerable restrictions on the progress of research and perhaps not even then. However, the standards and control methods in use are such, that the possibility of significant injury to employees as a result of exposure to radiation is extremely small compared with the chance of other types of injury.

In regard to the control methods used, one may reasonably conclude that they are adequate and achieve the basic objective; namely the safe execution of an advanced and diverse program of fundamental and applied research. However, one must hasten to add that many opportunities exist for improvements leading to reduction in costs and extension in the scope of technical activities that can be safely executed. The skillful application of existing methods is important and satisfying but the ever-present need for continual improvement is the challenge that makes the profession of Health Physics vital and worthy of the best efforts of all concerned.

Section 4. Reactor Facility—Materials Testing Reactor, Phillips Petroleum Co., Atomic Energy Division, Idaho Falls, Idaho

During the six and one-half years of full power operation of the Materials Testing Reactor as a high flux test facility, the average radiation exposure of personnel has been well below the permissible limits set by the AEC or the National Committee. Strict compliance with AEC standards for radiation exposure limits has not given rise to any serious problems. It might be anticipated that operation of a nuclear test reactor wherein several potentially hazardous experiments are inserted and removed on an average of each three weeks would provide a setting for a number of accidental overexposures as well as pose a large and continuing problem of keeping the exposure levels of the entire group of reactor personnel well within acceptable limits. However, while there have been some accidental exposures above normally accepted limits at the MTR, none has resulted in a lost time injury to the individual or in work restriction which caused a monetary loss to the individual or additional cost to the operation.

RADIATION EXPOSURE CONTROLS

Control of exposure at the MTR is primarily administrative, backed up by an adequate group of radiation monitoring personnel and area and air monitoring equipment. Although present AEC regulations do not require it, an administrative limit of 300 mrem in any one week is set as the extent to which any individual may be exposed to penetrating radiation without special consideration being given to the circumstances and justification for greater exposure. A further limitation is imposed that the total radiation in any period of thirteen consecutive weeks may not exceed 3 rem. If circumstances appear to warrant, a Branch Head in charge of operations, technical or maintenance work may request approval from the appropriate Assistant Division Manager for certain stated individuals to receive in excess of the weekly limit. Except in cases of emergency, this approval is requested in writing and states the individual's name, the maximum exposure requested, the work to be performed, the circumstances justifying the exposure and the individual's exposure record for the past thirteen weeks. If the Assistant Manager agrees with the need for the exposure and the requested limit he signs the exposure request and returns copies to the Branch Head and Health Physics Supervisor as authority to proceed with the work under the stated conditions.

All work with radioactive materials is carefully monitored before work begins and any job which could result in exposure greater than the daily portion of the weekly limit is continuously monitored by health physics personnel. As a further precaution, any work area which is not normally radioactive but could possibly have been subject to contamination is monitored before work is started in the area.

Occasionally it is necessary to expose an employee to radiation in excess of the weekly limit. These infrequent cases arise as a result of a requirement for a very specialized skill where strict adherence to the weekly limit would not permit enough time for one individual to

accomplish useful work in the radiation field. The result of strict use of the weekly limit would be the exposure of a series of individuals to the weekly limit without accomplishing the work to be done. In those cases where it is virtually necessary to exceed the weekly limit, prior written approval of the Assistant Manager is obtained and the work is continuously monitored and timed by a health physicist to insure that the authorized exposure level is not exceeded.

Work with radioactive materials presents problems of possible personnel and clothing contamination and ingestion and inhalation of radioactive particles or gases. When the possibility of contamination or ingestion and inhalation exists, special clothing and respiratory filters are used during the course of the work. If minor contamination is the only problem, the worker is issued coveralls, shoe covers and gloves for use in his work. For work in areas where radioactive dust does or could exist, the protective clothing is augmented by a dust mask which covers the worker's mouth and nose. Protection from radioactive gases which would not be retained by a dust filter is effected by use of a fresh air breathing apparatus which supplies clean air to the worker.

It is standard practice to decontaminate and shield work areas to a practical limit before permitting work in an area. Although special protective devices to be worn by the worker to reduce direct exposure are not practical in most instances, use is made of safety glasses to reduce eye exposure in fields of beta radiation.

Each individual is required to wear at all times a film dosimeter for measuring beta, gamma and, where advisable, neutron exposure on a weekly basis. In addition, the wearing of a gamma sensitive dosimeter is required on a daily basis. In cases where work may subject the individual to greater radiation than the daily portion of the weekly limit, an additional direct reading gamma dosimeter is issued to enable the worker and the health physics monitor to better evaluate the extent of exposure.

Since the greatest potential hazard to the reactor and personnel stems from the experiments conducted in the reactor, each experiment is given careful scrutiny by one or more trained and experienced engineers and is finally approved for insertion by our Reactor Safeguard Committee. This committee is composed of senior employees trained and experienced in nuclear physics, metallurgy, strength of materials, heat transfer, fluid flow and health physics. It is this committee's responsibility to approve for insertion only those experiments in which the maximum credible extent of all foreseeable potential hazards can be handled safely. The combination of careful engineering scrutiny and approval by the Reactor Safeguard Committee has resulted in an absence of major incidents and the occurrence of relatively few incidents of all kinds when consideration is taken of the great number of irradiations which have been performed in the MTR during the past six years.

Extensive instrumentation with continuous recorders and automatic alarms is present throughout the MTR area. Air monitors sufficiently sensitive to detect small fractions of the maximum safe levels of air concentrations of the most hazardous isotopes encountered locally are present in each separate area. These air monitors operate on a rate-of-rise principle which quickly detect the presence of significant quantities of radioactive materials. The level of activity

detected by the monitors is recorded and both visual and audible alarms are integral with each monitor.

Direct radiation monitors are present in even greater numbers. These instruments detect a rise in radiation level and activate visible and audible alarms at present radiation levels. Most of the direct radiation instruments are part of a monitoring system which records and alarms in the health physics office as well as initiating alarms in the area in which the instrument is located. Monitoring instruments in areas immediately surrounding the reactor are sensitive to thermal neutrons in addition to normal gamma sensitivity.

Major personnel exits from areas in which radioactive contamination is most possible are equipped with portal monitors to warn of the passage of significant contamination. Hand and foot monitors, to be used on a voluntary basis to detect personnel contamination, are present in convenient locations.

The above instrumentation is in addition to the constant surveillance provided by trained health physics technicians equipped with portable instruments for the detection and measurement of every type of radiation possibly present. As mentioned previously, these men constantly attend every job known to have significant radiation hazard and, in addition, watch for radiation hazard in all areas under their responsibility.

All personnel in the MTR area are required to wear film badges which are designed to provide a permanent record of the beta, gamma and fast neutron exposure of each individual. Direct and indirect reading dosimeters are also used to provide a rapid estimate of the gamma radiation received. Urine samples of all personnel are obtained periodically to assure that no hazardous build-up of internally fixed radioactive materials is occurring.

The Idaho Operations Office of the Atomic Energy Commission provides the service which determines and reports to us the exposures indicated by film badges and indirect reading dosimeters as well as results of urinalyses. The results are permanently recorded in the AEC laboratory files and in our own files. As we receive them, the results are added to previous exposure and distributed to appropriate health physicists and supervisors to aid them in controlling further exposure.

The radiation exposure limits observed at the MTR are those advocated by the National Bureau of Standards Handbooks 52 and 59. Certain chapters of the AEC Manual are also applicable and, where they are more restrictive than the NBS handbooks, the lower limits are used.

EXPERIENCE IN RADIATION EXPOSURE

The control procedures and permissible exposure limits under which the MTR has operated have been effective in maintaining a low level of exposure to personnel except for a few cases where equipment failure and malfunction or human error have resulted in incidents wherein some employees received greater than the maximum permissible weekly exposure.

Operation of the reactor with a continuous load of approximately 500 separate experiments, and the insertion or removal of a number of experiments each three weeks sets the stage for occasions when

radioactive material is released either to the atmosphere outside the reactor building or within the building itself. Over the period of reactor operation from 1952 to the present, these accidental releases have not resulted in physiologically significant exposure to personnel but have necessitated several building evacuations. During calendar years 1955 and 1956 there were 24 cases of significant releases of radioactive materials which necessitated 9 building evacuations except for personnel wearing respiratory protection. Total evacuation time for unprotected personnel was 42 hours during the two year period. In 1957 there were 7 cases where radioactive material was released from an experiment resulting in 4 building evacuations for short periods of time.

In July 1956, the most serious direct radiation exposure incident occurred in the history of the MTR. The incident occurred during installation of an experiment in the reactor tank. In order to fasten piping and lead tubes from some experiments it is necessary to lower the water level in the tank about six feet to permit a man in a bosun's chair to enter the tank to place and tighten the clamping mechanisms. Prior to lowering the water level it is necessary to remove the beryllium discharge tube plug from a rack above the core where it is normally located during reactor down periods and place the plug at a lower elevation on top of the reflector section. This is done to permit lowering the water level and still have adequate shielding over the highly radioactive parts of the internal structure. Up to the time of this incident, it was standard operating practice to require a health physics technician to be present while the water level was being lowered and to stay until a thorough survey had been made of the radiation field and a safe working time established. All of these things were done prior to work on the experiment installation but during the course of the installation the discharge tube plug in its location on top of the reflector interfered with the experiment insertion so one of the men picked up the plug with a handling tool and thoughtlessly placed it back in the rack from which it had been removed prior to lowering the water level. This act exposed the top of the plug above the water and greatly increased the radiation level in and around the top of the tank. Although this error was quickly recognized, eight men received exposures. Three men received an exposure between 2 and 3 rem, one man 4 rem, two men 6 rem, one man 10.6 rem, and one man 21.5 rem. Seven of the men were restricted from work in potentially radioactive areas for periods ranging from 9 to 68 weeks. These work restrictions did not involve reassignment to other work except in the case of the man receiving 10.6 rem. His normal assignment had been supervision in the reactor area whereas after the incident he was assigned to supervisory work in an area apart from the reactor. Following this incident, a requirement was established that a health physics technician must be present at all times when any work is performed in the tank.

Three other incidents in which personnel received exposures in excess of recommended quarterly limits have occurred but the maximum exposure was 5 rem. In three additional cases the circumstances were such that high exposure could have occurred but fortunately did not.

Every case of equipment or personnel failure is thoroughly investigated by an Accident Review Committee composed of senior per-

sonnel. The committee makes recommendations for procedure and equipment changes to prevent the occurrence of similar incidents.

It is felt that the control procedures and standards used at the MTR have been effective in limiting the average exposure of personnel to a level well below that currently considered acceptable. More restrictive limits would probably not prevent an occasional accidental exposure in excess of weekly or quarterly limits, but such exposures are the rare exception in our experience thus far.

PART IV

RADIATION PROTECTION IN THE AEC LICENSING PROGRAM

Section 1. AEC Regulatory Responsibility Under the Atomic Energy Act of 1954

In adopting the Atomic Energy Act of 1954, Congress placed upon the Atomic Energy Commission the responsibility for regulating, through a system of licensing private atomic energy activities, so as to promote the common defense and security of the nation and to protect the health and safety of the public. It thus became necessary for the Commission to translate the knowledge and experience gained from its own operations and that of others into regulations which would protect atomic workers and the public and yet not hinder the development of an atomic energy industry. In this connection the recommendations of the ICRP and the NCRP concerning radiation exposure standards have been particularly valuable. In establishing its regulatory program the Commission has undertaken to avoid a rigid pattern of licensing and regulation which might in practice prove unworkable or excessive, and has instead sought to provide the maximum feasible degree of flexibility in its controls consistent with safety. The Commission believes that, within the limits of assuring protection of the public health and safety, its regulations do not impose unnecessary restrictions upon private participation in the development of the peaceful uses of atomic energy.

Section 2. Mechanism for Discharging Regulatory Responsibility

The Commission has developed and placed into effect seven basic regulations governing the construction and operation of reactors and other nuclear facilities, and the possession, use and disposal of source (natural uranium and thorium), byproduct (radioisotopes), and special nuclear materials (Uranium 233, 235, and plutonium).

These regulations have been published in the Federal Register as part of the Code of Federal Regulations.

10 CFR 20—"Standards for Protection Against Radiation"
10 CFR 30—"Licensing of Byproduct Material"
10 CFR 40—"Control of Source Material"
10 CFR 50—"Licensing of Production and Utilization Facilities"
10 CFR 55—"Operator's Licenses"
10 CFR 70—"Special Nuclear Material"
10 CFR 71—"Regulations to Protect Against Accidental Conditions of Criticality in the Shipment of Special Nuclear Material"

The procedural regulations governing notice and hearing are contained in 10 CFR 2.

REGULATIONS

The licensing regulations specify that no person within the United States shall transfer, acquire, own, possess or use any production or utilization facility or any source, special nuclear, or byproduct material except as authorized by a license issued by the Commission or an exemption therefrom. The regulations specify the procedure for submitting an application for a license, the general and specific requirements for issuance of licenses, and the terms and conditions which are a part of each license. For example, they specify such things as (1) the type of information that must be submitted by applicants for licenses, (2) the criteria for radiation protection, (3) the criteria for approval or disapproval of licenses, (4) requirements for transfer of licensed materials, (5) recordkeeping requirements, and (6) rules relating to the amendment, modification, suspension or revocation of licenses.

The general requirements for approval of an application for a license are:

(*a*) The use is for a purpose authorized by the Atomic Energy Act of 1954, as amended.

(*b*) The applicant is qualified by training and experience to use the material for the purpose requested in such a manner as to protect health and minimize danger to life or property.

(*c*) The applicant's proposed equipment and facilities are adequate to protect the health and minimize danger to life or property.

(*d*) The applicant's proposed operating procedures designed to protect health and minimize danger to life and property are adequate.

Each licensee is required to confine his possession and use of licensed material to the location and purpose authorized in the license. Licensed material may be transferred only to other licensees authorized to receive it.

10 CFR, part 20, "Standards for Protection Against Radiation," is the Commission's basic regulation dealing with radiation protection and applies to all persons who receive, possess, use, transfer, or dispose of source, byproduct, and special nuclear material or who operate production or utilization facilities. It establishes technical standards and precautionary procedures for the protection of the licensee, his employees, and the public from radiation hazards. The technical standards include maximum radiation doses individuals may receive, maximum radiation levels in unrestricted areas, maximum permissible concentrations of radioactivity for discharge into air and water, and permissible methods and concentrations for the disposal of low levels of radioactive waste.

The required precautionary procedures help assure compliance with the technical standards and include requirements for personnel monitoring, radiation surveys, posting of areas and equipment with radiation caution signs, instruction of personnel, storage of licensed material. The purpose of the reporting requirement is to provide timely notice to the Commission of serious incidents involving licensed materials so that the Commission can assure that appropriate

steps are taken to protect against radiation hazards. The reporting requirement specifies immediate, 24-hour or 30-day notification depending upon the seriousness of the accident. The type of accidents which must be reported to the Commission are those which involve overexposure of persons to radiation, release of radioactive materials in excess of the regulation, loss of operating time of a facility, and damage to property in excess of certain limits.

LICENSING PROCEDURES

General

The principal purpose of the licensing requirement is to enable the Commission to make a determination that the applicant will be able to comply with all applicable regulations including part 20, "Standards for Protection Against Radiation" and any special conditions to be included in the license. The information required of the applicant is designed to provide the Commission with sufficient knowledge of the proposed program to make this determination. Each phase of the applicant's proposed program is carefully evaluated by the Commission's technical staff to determine that the conditions of use will not be inimical to the health and safety of the public.

Materials

Radiation protection is the principal factor considered in licensing the possession, use, processing or disposal of source, special nuclear and byproduct material. Source material is defined in the Commission's regulations as any material except special nuclear material, which contains by weight 0.05 percent or more of uranium, thorium or any combination of these two elements. For example, one form is the raw ore or mineral as it comes from the earth. Source material also includes concentrates of uranium or thorium, salts, compounds, alloys or the refined uranium or thorium metal itself. The information required from an applicant for a license to use any of these forms of source material varies according to the degree of potential radiation hazard presented by the use of a particular form of material for the intended purpose. It should be noted that since the radioactivity of source material is low the relative potential radiation hazard is also low. In general, the Commission is interested in knowing the type and amount of material involved, a description of the proposed use, the radiation safety procedures to be followed and the type of radiation surveys to be conducted, the type of radiation instruments available, and the method of waste disposal. Uses of source material which have been licensed include processing of uranium ores for concentrate or feed materials for production process or reactor purposes, manufacture, fabrication and use of thorium-magnesium alloy in aircraft and missile components, use of depleted uranium for pilot plant studies on uranium processing, use of uranium in glass, ceramic and electronic parts, and use of uranium and thorium in chemical and biological research.

The transfer of certain products containing small quantities of source material are exempt from licensing. These include such products as incandescent mantles, glass items, photographic film, ceramic products and vacuum tubes. Similarly, small quantities of source material may be received and used under a general license without filing an application or receiving a specific licensing document.

Such uses include medical, educational, or analytical by hospitals, physicians, educational institutions, and research laboratories.

In reviewing applications for licenses involving special nuclear material, depending upon the type of material, amount, form and degree of enrichment, an additional and more significant potential radiation hazard must be considered—the possibility of accidental assembly of a critical mass of the material which would initiate a chain reaction. The applicant for a license must describe in detail his proposed equipment, procedures, and training to avoid conditions under which accidental criticality might occur. The information submitted by the applicant must provide assurance that the pattern of handling the material is such that no one human error could cause a criticality accident. The applicant must also demonstrate the adequacy of management and administrative techniques to be employed to assure that the safety procedures are in fact followed. Specific examples of applications where such considerations are involved include processing of special nuclear material for reactor fuel, reactor fuel fabrication, loading and unloading of reactors, and transportation of special nuclear material. In this regard it is important to note that the Commission regulation 10 CFR 70 was recently amended to require each licensee authorized to possess more than certain specified quantities of special nuclear material to install and maintain a radiation monitoring and audible alarm system capable of detecting a critical reaction and giving immediate warning to persons in the area of its existence so that protective measures may be taken. The monitoring and alarm system to be used by each applicant or licensee must be approved by the Commission. Further, the Commission's regulation 10 CFR 71 establishes requirements for transporting special nuclear material to protect against accidental conditions of criticality. Specifically, the regulation limits the amount of material a licensee may transport himself or transfer to a common carrier without specific approval of his container design and transportation procedures by the Commission.

Small quantities of special nuclear material are used principally in research and development activities where the type and degree of radiation protection control depends on the particular use involved. However, since the amount of material usually involved is no more than a few grams, the radiation exposure potential is low.

Applicants for a byproduct material license must submit an application form giving information on the kind and amount of radioisotope desired, the proposed use of the material, the instruments available for radiation measurement and monitoring, the training and experience of the persons responsible for the use of the material, and the procedures and precautions to be employed in assuring radiation safety. In the case of specific applications such as radiography, teletherapy, gamma irradiators and waste disposal services, certain additional supporting information pertinent to the proposed program is necessary. For example, applicants for industrial radiography must indicate the make and model number of the radiography device to be used so that its radiation safety characteristics may be evaluated, the field location of use, radiation survey procedures, and procedures for leak testing the sealed source, if necessary. Applicants for teletherapy or irradiators must indicate the type and amount of shielding used, calculated

radiation levels outside the facility, safety interlocks employed, and operating and emergency procedures.

Radioisotope applications cover a broad spectrum of uses in many fields. Radioisotopes are used in medicine in diagnosis and treatment of various diseases and in research; in industry, in radiography, gaging, tracer applications, applied radiation, luminous markers, batteries, static eliminators, electron tubes, and in industrial research; in agriculture, in determining efficiency of fertilizers, effecting plant and animal mutations, and many research projects; and in universities for teaching and conducting research. The radioisotopes involved vary widely in type, amount, form, half-life and type of radiation emitted. Each category of radioisotope use presents its own particular radiation safety problems which must be evaluated in licensing.

The Commission has determined that small amounts of certain byproduct materials may be safely used under general license as set forth in part 30 of the Commission's regulations. Part 30 also provides that certain devices containing comparatively small amounts of byproduct material may be distributed under a general license when they are manufactured and tested under the conditions of a specific license. These products include static eliminators, vacuum tubes, light meters and ion generators.

Facilities

The licensing of facilities, reactors and critical experiment facilities is accomplished in two steps; first, by the issuance of a construction permit, and, second, by the issuance of a license to operate the facility. Each applicant for a facility license for a nuclear reactor or a critical experiment facility is required to provide, to the Commission's satisfaction, reasonable assurance that the proposed facility can be constructed and operated at the selected site without undue risk to public health and safety, either from accidental release of radioactivity or from routine operations.

The general nature of the information which an applicant for a facility license must submit to the Commission is set forth in the Commission's regulation entitled "Licensing of Production and Utilization Facilities" (10 CFR, pt. 50). If sufficient information is available to provide reasonable assurance that the proposed facility can be constructed and operated at the proposed location without undue risk to the health and safety of the public, a construction permit may be issued. Before issuing the permit, the Commission either directs the holding of a hearing or provides opportunity for hearing by appropriate notice published in the Federal Register.[8] Upon completion of the facility, the construction permit may be converted to an operating license if the Commission finds that the reactor has been properly constructed and may be safely operated. This finding is not made until final information (including proposed operating procedures) submitted by the applicant has been reviewed and the reactor has been inspected by the Commission staff. Public hearings may be held regarding the conversion of construction permits into operating licenses in the same types of situations as in the issuance of construction permits.

[8] Public Law 85-256 requires that the Commission hold a public hearing before issuing any construction permit or license on an application filed under sec. 103 or 104B of the act or under sec. 104C for a testing facility.

Since the release of the radioactive materials contained in a nuclear reactor could constitute a serious hazard to public health and safety, a primary purpose of the Commission's hazard evaluation procedure is to assure that the probabilities of accidentally releasing this material are kept to an acceptable minimum.

The possible releases from normal operations of a reactor are relatively easy to control even with a unique design. In routine operations, the problems are chiefly those of governing the release to the environment of reactor coolants such as air or water in such a way as to avoid excessive concentrations of radioactive materials.

Determining the probability and nature of possible reactor accidents which might release radioactive materials is more difficult. For this purpose, evaluation of reactor hazards requires a complete study of all aspects of the reactor design and operation to determine, on the basis of the best available information, what could possibly go wrong with the reactor and what steps are being taken to prevent an accident. For this purpose, the applicant's engineers and scientists must critically review each phase of the reactor design and operating procedure both in itself and also in its relationship to the integrated whole. They must carefully consider the inherent nuclear, chemical, metallurgical, physical, and mechanical characteristics of the fuel, the moderator, the coolant, the neutron absorbers and structural materials in relation to the similar characteristics of the control and safety systems; the heat removal system, and the pressure systems. The object is to assure that the probability of an operating mishap has been brought to an acceptably low level. Further, the engineers and scientists, while concerned with determining that reasonable steps have been taken to prevent escape of radioactive fission products from the reactor core, must recognize that, in spite of all precautions, the most unlikely series of events might take place. Therefore, the designers must consider what events could occur which would release radioactive materials from the reactor core, and determine what further safety precautions should be provided to prevent serious consequences for such highly unlikely accidents. This aspect of the safety evaluation must deal with the relationship of reactor location to its containment; selection of the site on the basis of pertinent radiological safety factors; hydrology, meteorology, and seismology; estimates of present and future population density of the surrounding areas; estimates of the use to which surrounding areas will be put, including industrial, commercial, agricultural or residential purposes; and the possible use, by man or animals, of surface or ground waters that might be subject to contamination by the reactor.

Since it is frequently impractical for an applicant to submit a complete hazards summary report at an early stage in his planning, procedures are established by which the results of the hazards evaluations can be submitted step by step as a series of preliminary reports. When the Commission is satisfied that a facility of the general type proposed can be constructed and operated at the proposed location without undue risk to the health and safety of the public, it may issue a provisional construction permit.

Ultimately, the Commission expects to develop standards which will make it possible for the designer of a nuclear reactor to know in advance that by incorporating certain design features, establishing

certain relationships between his location and the containment plan of his reactor, and by following certain operating procedures, he will meet the Commission's safety requirements for a license. At present—while the industry is in the developmental stage and most reactors differ from others in important aspects—it is undesirable to issue as regulations anything more than general standards and guides for reactor safety.

The Commission places in its Division of Licensing and Regulation the responsibility for making the necessary evaluation and review of hazard analyses, for assessing the reasonableness of the assurances that the health and safety of the public will not be endangered, and for recommending the terms and conditions to be included in construction permit and license.

Public Law 85–256 requires that applications for nuclear facilities under Section 103 or 104B for power reactors and under 104C for testing facilities be referred to the Advisory Committee on Reactor Safeguards, for its advice. The Commission, through its Division of Licensing and Regulation, also refers to the Committee other reactor projects presenting significant safety questions. Also, general problems of reactor safety, principles, policies, standards and criteria are discussed with the Committee before formal adoption by the Commission.

When an application for license authorizing construction and operation of a nuclear reactor is received, the application and related documents filed in the proceeding are collected and made available for public inspection. A notice of the receipt of the application is published in the Federal Register and letters are sent to appropriate state officials notifying them of receipt of the application. The same action is taken with regard to hearings and the issuance and amendment of construction permits and licenses. A copy of the hazards analysis made by the Commission staff and, where applicable, a copy of the report by the Advisory Committee on Reactor Safeguards are also made available for public inspection.

Operators

There is one additional licensing step associated with reactor operation and this is the examination and licensing of reactor operators, the persons who manipulate the reactor controls. In order to qualify for an operator's license, the applicant must show, by medical examination, that his physical condition and general health would not result in operational errors which might endanger public health and safety. In addition the applicant must have satisfactorily passed an operating test as well as a written examination given by the Commission which tested his understanding and familiarity with such aspects of the facility as general design and operating characteristics, control and safety mechanisms, all control station instrumentation, standard operating procedures, and other phases important to safe operations.

INSPECTION

Introduction

The Commission's inspection function, as a part of its regulatory program, is designed to provide an independent and first hand review of the licensee's operation. The basic objective, as in other regulatory functions, is the safe use of radioactive materials and the safe

operation of production and utilization facilities. The specific objectives of the program are the following:

(*a*) To gather factual data on compliance of a licensee with applicable rules and regulations and with special conditions incorporated in his permit or license.

(*b*) To investigate radiation accidents and incidents; to determine status of compliance on the part of the licensee; to determine the cause of the incident and to review the corrective action taken to minimize the danger to the health and safety of the public.

(*c*) Incident to these inspections and investigations, information is collected which may be of assistance to the Commission in determining the adequacy and effectiveness of other phases of its regulatory program.

The program is divided into two major parts, corresponding to the two major categories of licensed activities:

(*a*) Use of licensed materials.

(*b*) Construction and operation of production and utilization facilities.

Material licensees

In this category, activities are licensed for the use of byproduct material, source material, and special nuclear material.

The system for inspection of materials licensees is established on a decentralized basis. Accordingly, the inspection functions have been organized in 8 of the Commission's 12 Operations Offices. Each office is assigned a responsibility for inspection of licensed users of material in a specified geographic area, which consists of an integral number of two to ten states. This arrangement provides reasonable geographic proximity of the licensee and the inspector, and at the same time, permits the establishment of continuing and useful contact both with licensees and interested state agencies.

A General Inspection Guide was issued, in preliminary form, to provide guidance and uniformity of inspection throughout the field offices. The Guide has since been revised once and is still used in draft form to permit further changes and revision as dictated by experience.

The kinds of operations and of radioactive materials vary from those involving small and relatively innocuous quantities to those involving large amounts and especially hazardous forms of materials. Inspection experience with regard to the various types and kinds of operations is being analyzed and studied. As a result, the priority and frequency of inspection are determined by the hazard involved. The less hazardous activities are inspected least often, allowing the efforts of inspection personnel to be properly focused on these activities more deserving of attention.

Facilities licensees

The inspection of production and utilization facilities is more complex than that of the vast majority of operations involving licensed use of materials. The inspection of such facilities is concerned with two principal factors:

(1) The facility and its material, structural, instrumental and control characteristics; and

34434—59——5

(2) The people who operate the facility, their training, organization, the operating procedures they follow and their supervision.

The inspection of production and utilization facilities is performed by Washington Headquarters personnel. They officially enter the picture upon issuance of a construction permit. However, the extent and complexity of many reactor projects are such that it is necessary to initiate study from their inception.

During construction, inspections are made to determine that plans and specifications contained in the application for license, and special conditions of the construction permit, are being met. As construction approaches completion, tests of equipment are reviewed and preoperational integrated test runs are observed. At this stage, the initial trial of operating procedure is possible.

It is also at this time that the project evolves from a phase of "preparation of a facility" to that of "the management of a facility."

On the basis of such tests and trial of procedure, and on observation of the operating organization, its discipline and familiarity with procedure, recommendation regarding issuance of license for the operation of the facility is made by Inspection personnel.

When a license for the facility is granted, initial start-up and operation are observed. During this period, characteristics of the reactor and auxiliaries and the effectiveness of organization and procedure are noted and reviewed against the conditions of the license. Information gained from actual operating experience is provided, at this time, which is of value to the Commission for evaluating its regulations. Periodic inspection visits thereafter are made to the operating facility, and any findings and recommendations are considered by appropriate Commission staff.

AEC regulation 10 CFR, part 20, "Standards for Protection Against Radiation" defines three kinds of radiation incidents and requires that each licensee must report such occurrences to the Commission. The definition implies three levels of severity, the first of which is of such severity that an immediate report and institution of remedial action is required. The other two kinds are in the order of decreasing severity and the reporting and investigative requirements, therefore, are less stringent. The procedures for investigation of these incidents are directly referred to the degree of severity and hazard presented in each case.

COMPLIANCE ACTIONS

Inspection reports of licensees' operations are reviewed in regard to items of noncompliance with Commission regulations or conditions of licenses reported by the Commission's Inspection Division. These items are brought to the licensee's attention formally as a notice of alleged violation issued under the Commission's "Rules of Practice," 10 CFR, part 2. The licensee is given 30 days to reply describing the corrective action taken or to be taken to correct the deficiencies stated. In cases where, in the opinion of the AEC, immediate danger to the public health, safety and interest requires, a temporary suspension order may be issued halting those operations involving licensed material deemed hazardous without a previous notice of alleged violation having been issued. Following either of these actions an order for the licensee to show cause why his license should not be modified,

suspended or revoked may be issued and the matter may be set down for a hearing. As a result of the hearing procedure a license may be suspended, modified or revoked by the Commission. In addition the Commission may impose requirements by order upon licensees or construction permit holders concerning which the licensee may request a formal hearing.

Section 3. Current Status of Licensing Program

As of November 1958 there was a total of approximately 6,200 holders of licenses for the possession and use of source, byproduct, and special nuclear material and the construction and operation of utilization facilities. Of these, about 4,400 represent byproduct material, 1,500 source material, 240 special nuclear material and 61 utilization facilities. A breakdown of the material licensees by State and a list of facility construction permits and licensees are given in appendix C–1 and C–2 respectively.

From August 2, 1946, to November 30, 1958, approximately 609,000 curies of byproduct material in over 117,000 shipments have been made by the Oak Ridge National Laboratory, the Commission's principal radioisotope supplier, to AEC licensees. The number of curies and shipments for various isotopes are given in appendix C–3.

Section 4. Radiation Safety in Specific Programs

RADIOISOTOPES

The largest category of radioisotope licensees are medical institutions and private physicians. The majority of medical users are concerned only with the short-lived radioisotopes, Iodine 131, Phosphorus 32, and Gold 198 for diagnostic and therapeutic use. Diagnostic radioisotope uses are essentially tracer applications and involve only microcurie amounts of radioactivity. Even the therapeutic applications usually involve low millicurie amounts (10–200 mc.) of material per treatment. Medical research programs involve the use of microcurie or low millicurie quantities of such isotopes as Ca^{45}, H^3, Fe^{55-59}, C^{14}, S^{35}, Na^{24}, and K^{42}. The radiation exposure potential to operating personnel is low for this category of isotope use. Small amounts of radioactivity are used according to standard, routine procedures. Such programs are under the supervision of highly-trained, professional persons.

Sealed sources of various types containing Cobalt 60 and Iridium 192 are used as interstitial implants for treatment of cancer. The level of radioactivity involved is usually in the millicurie range. Here, too, the material is used according to strict procedures by radiologists. Large amounts of Cobalt 60 are used in teletherapy units for treatment of cancer. In this case radiation safety is accomplished by built-in protection. The source itself is contained in a properly shielded unit equipped with such safety features as lights to indicate whether the source is on or off, automatic return of source to shielded position in the event of power failure, and provision for manual return of source to shielded position in the event of failure of the automatic source return system. The facility in which the unit is used is properly shielded to control exposure of persons outside the facility and it is equipped with safety interlocks to prevent persons from entering the

room when the unit is on. The unit is operated according to standard procedures under the supervision of a radiologist.

Industrial licensees constitute the second largest group of isotope users. In industry the use of radiation is centered around radioisotopes in sealed sources. The radioisotope is incorporated into a container which is sealed in a manner designed to prevent leakage of the radioactive material under expected conditions of use, transportation and storage.

Sealed source applications account for about 80 percent of the industrial users and include such uses as radiography, various types of gaging, luminous markers and oil well logging. A sealed source reduces the potential radiation hazard by minimizing the possibility of contamination and internal radiation exposure during use. However, steps must be taken to control external radiation exposure from such sources. Sealed sources vary in size from a few millicuries in beta thickness gages, to a few curies for radiography, to thousands of curies for irradiators.

Over 500 firms are licensed to perform radiography with radioisotopes. These firms employ chiefly sealed sources of Cobalt 60, Cesium 137 and Iridium 192 in activities ranging from 1–100 curies per source. Two methods are used to handle such sources. Sources up to 1 curie of Cobalt 60 or radiation equivalent or other isotopes are commonly handled in the open by a remote handling device or "fish-pole". Sources up to 100 curies are used in shielded exposure cameras.

Of the various industrial uses of radioisotopes, radiography presents the greatest potential for radiation exposure. Relatively large amounts of radiation are being handled, often under constantly changing conditions, by persons having a minimum amount of training in the principles and practices of radiation protection. Therefore, each licensee is required to assure that the radiographer is supplied and is thoroughly familiar with detailed written administrative and operating instructions and with radiation safety control procedures which outline step by step his responsibilities and how they are to be carried out.

Industrial gaging is the second large area of isotope use in industry. There are about 500 firms using thickness, density, level and composition gages containing radioisotopes. A total of over 4,000 of these gages are presently in use. Beta thickness gages usually employ sealed sources of Strontium 90 or Krypton 85 in activities of 10–20 mc. and 20–250 mc. respectively. Density and level gages usually contain gamma-emitting sealed sources of Cobalt 60 or Cesium 137 in amounts from 25 mc. to 1 curie. Radiation safety in these applications is dependent principally upon "built-in" protection through proper shielding, safety interlocks, and reliable sealed sources.

There are virtually unlimited uses of radioisotopes for luminescent purposes. Strontium 90, Krypton 85 and Tritium are being widely used in luminous markers for safety marking in aircraft, mines, ships and public buildings; for low level illumination and standard light sources. Polonium 210 is used for static eliminators and Nickle 63, Cesium 137, Cobalt 60 and Krypton 85 are used in electron tubes to improve firing characteristics. Radiation protection is almost entirely dependent upon a reliable sealed source.

About 100 firms have been licensed to use high level gamma irradiators containing more than 100 curies of Cobalt 60 or other isotopes.

Most irradiators contain kilocurie amounts of Cobalt 60. The total amount of Cobalt 60 licensed for this purpose is about 400,000 curies. About five firms are licensed to use spent fuel elements for irradiation work. Consideration is being given to designing irradiators which will contain megacurie amounts of Cobalt 60. All of these applications involve radiation installations with elaborate shielding, safety interlocks and radiation warning systems. Strict radiation protection control procedures for operations and emergency plans are necessary.

Typical routine industrial tracer applications with radioisotopes include interface marking in oil pipelines, wear studies, catalyst circulation in refineries, and chemical process control. Radiation safety depends on the use of low levels of short half-lived radioisotopes and controlling the concentrations of radioactive material in such a manner that negligible concentrations of radioactive material remain in the final product.

Commercial processors and suppliers of radioisotopes and sealed source manufacturers handle bulk, curie amounts of long half life alpha, beta, and gamma-emitting radioisotopes. Radiation exposure is controlled by the use of special facilities to control contamination such as ventilated hoods and glove boxes, properly shielded work areas, and specific operating and emergency procedures. These operations are supervised by technically qualified personnel.

University and research laboratory radioisotope programs are quite diversified and involve a wide variety of radioisotopes, chemical and physical forms, and amounts. However, the typical university program does not usually involve large quantities of radioisotopes. The degree of radiation safety control depends on the particular program involved but the precautions consist chiefly of careful laboratory techniques to control contamination of persons and equipment and in some cases localized shielding to control radiation levels and personnel exposure.

SPECIAL NUCLEAR MATERIAL

As mentioned previously, the potential for significant radiation exposure is great in the event of accidental criticality. Therefore, in working with large quantities of special nuclear material, radiation protection depends upon the establishment and continual enforcement of strict operating, administrative, and accountability procedures to assure that a "critical mass" of material will not be accumulated. Personnel involved in such operations must be thoroughly indoctrinated in emergency procedures to be followed in the event of such an accident. In addition, the Commission's regulation, 10 CFR 70, requires a radiation monitoring and alarm system when amounts of of special nuclear material sufficient to create a critical mass are being used to warn personnel in the area so that appropriate action may be taken.

SOURCE MATERIAL

In regard to the licensing of source material, the Commission recently completed a study of the operating uranium mills which process uranium ore into a concentrated uranium product to identify areas where significant radiation exposures may be occurring and determine what corrective action would be necessary. In general, the survey indicated that additional dust and effluent control measures

were necessary. Dust control is particularly important in the ore grinding and the final product areas. Meetings have been held with U.S. Bureau of Mines. U.S. Department of Labor, U.S. Public Health Service, the eight Western States in which the mills are located, and the companies operating the mills to emphasize the need for further evaluation of the radiation safety problems presented by mill operations and further regulating controls by which necessary corrective action would be required.

Radiation safety in other operations involving the use of source material depends primarily on controlling contamination of equipment and areas and concentrations of radioactivity in the air during such operations as grinding, welding, and melting. Control procedures for external radiation exposure may be necessary for certain applications such as direct handling of sourse material as alloys or compounds containing source material.

FACILITIES

In the case of reactors and critical experiments, numerous reviews during the licensing process insures that there are adequate safeguards, through the design and operating procedures, to protect workers and the public from radiation exposure under routine operating conditions. The chief control procedure during routine operations is maintaining the release to the environment of reactor coolants, such as air and water, within permissible levels. In each case where maintenance or repair is necessary, the radiation exposure potential can be evaluated and specific control procedures established. However, significant radiation exposures are possible from credible accidents. Even in such unlikely instances, procedures have been established to minimize the radiation exposures which might result.

PART V

RADIATION PROTECTION TRAINING

INTRODUCTION

In the operation of the Commission's diversified and decentralized activities, a variety of radiation hazards are encountered—each with its own characteristics. Because of this, the requirements for training employees to live with radiation in the day-to-day conduct of their jobs are best met by individually styled training programs.

The bulk of training activity found in the atomic energy program is conducted by AEC contractors because it is in contract operations that hazards are most frequently present. The contractor employee working in the production plant or the research laboratory—if he is exposed at all to radiation or if the possibility of exposure exists—must know what radiation is and how to work in its presence.

AEC contractors, therefore, as part of their management responsibility, develop and conduct training programs best suited for the particular hazards associated with their operations. These programs are discussed below.

Comparatively few AEC employees have duties requiring them to work in the presence of radiation. For this segment of its own employees, AEC conducts specialized training programs. These are summarized following the discussion of contractor training programs.

In addition to the direct training *conducted by AEC* for its own employees and other governmental groups such as State and municipal fire protection agencies, the AEC *supports* training of State radiological health personnel and provides a limited number of fellowships at academic institutions for the study of industrial hygiene, industrial medicine and related subjects.

These programs as well as the training activities conducted by other Federal agencies on radiation protection will be covered in the final portion of this overall section on training.

Section 1. Programs Conducted by AEC Contractors

The training given by contractors during 1957 was designed to prepare their employees to understand and work with the radiation aspects of their jobs. Courses were given to cover: (*a*) orientation or indoctrination in the general subject of what radiation is and the problems it poses for the worker; (*b*) general company rules and policy concerning radiation protection; (*c*) special training for those employees who would encounter special hazards in their jobs; and (*d*) programs designed to train health physicists, industrial hygienists, radiation monitors and others whose full-time jobs are radiation protection.

Radiation itself occurs in many different types of activities under widely varying circumstances, and at all levels of intensity. As a consequence, the training needed by workers to understand and work with radiation sources can take a number of different forms depending on the nature of the problem and the current state of employee training. Such training programs do not easily fall into clearly definable categories and discussions of them tend to understate the importance of such informal training techniques as posters and pamphlets, on-the-job experience and the daily instruction and guidance which a supervisor gives his employees. Emphasis should also be placed on the importance and effectiveness of policy and administrative procedure in assuring safe work practices regarding radiation hazards. Such policies and procedures are an integral part of radiation protection training.

In many instances accurate counts cannot be made of the number of contractor employees receiving each type of training. Therefore, figures given here fall short of indicating the actual total number trained in 1957. Also, some training courses of importance given less frequently than annually may not have been conducted in 1957 and therefore are not taken into account.

In order to group the courses in a systematic fashion, four categories were used, defined in terms of the level of difficulty and scope of each course.

Two levels were used—*basic* and *advanced*—and the scope of the subject matter divided into a *general* and a *specific* category. Since the substantive features of the training courses under consideration were already limited to radiation safety, hazards and other closely re-

lated areas, the *general* and *specific* categories were felt to be adequate. The four categories are defined as follows:

Basic general—includes courses designed to orient and/or familiarize all employees with little or no prior knowledge of the subject of radiation. Examples of courses in this category are: "General orientation courses"—given to all employees of a contractor establishment on a routine basis; and "Basic fundamentals relating to hazards."

Basic specific—includes training, elementary in its approach to the subject, but limited in scope to certain specific areas within the subject of radiation. This category includes such courses as "Orientation and Van de Graff Machine Work," "Criticality Drills" and "SRE Training."

Advanced general—covers training courses in the entire field of radiation safety which, in level of difficulty extends beyond the elementary level. The substantive elements of these courses presume some prior knowledge of the theory and principles of radiation protection. Examples of courses in this category are: "Advanced Radiation Safety Training," "Advanced Indoctrination," and "Graduate Study in Health Problems." The instruction categorized in this group ranges in duration from 1 or 2 hour lectures on theory to as much as 6 months of intensive training.

Advanced specific—as in the advanced general category, presumes some prior theoretical knowledge. These courses, however, are limited to specific subjects within the field of radiation protection such as: "Technical Squad Training," "Resident Physician's Clinical Training Program," and "Health Physics and Critical Facility Technical Training."

The most common form of training offered by contractors was some form of *basic general* course given to all employees whatever their jobs. These were usually lecture or film presentations, of no more than 1 to 3 hours duration, giving a brief explanation of what radiation is and how its hazards are controlled. In some plants, modifications of this type of course are given occasionally as refreshers.

A wide variety of *basic specific* courses were given, aimed either at special groups of employees or at particular areas of subject matter. Employee groups included fire fighters, reactor operators, radiation monitors, hot cell facility operators and process operation employees. Also many other courses were conducted for departments with special problems and for first-line supervisors. These courses generally ran 15–20 hours per employee and are given once as a unit, or split into short components and spread over the work year. The curriculum of an illustrative course in this category offered to supervisory personnel in an irradiation processing department covered the following subjects: radiation physics, radiation dosimetry, biological aspects of radiation, the monitor's job, measuring and detecting equipment, interpretation of instrument readings, monitoring techniques, control of access to radiation, control of radioactive contamination, permanent radiation records, protective clothing and the exposure records program.

Basic specific courses were also conducted on radiation problems related to such subjects as industrial toxicology, nuclear engineering, criticality drills and detection instruments.

Advanced specific courses were designed to cover much the same area of subjects as the *basic specific* except that instruction was normally more complex, more detailed and of greater duration, running 25 to 30 hours each. These include such special courses as industrial ventilation problems, damage control and exposure counting statistics. An example of a course in this category is one offered by a production contractor to its 20 monitors in the field of mathematics. Basically the course—given by Health Physicists—consists of classes and problem assignments in algebra, exponents and trigonometry to provide necessary facility in radiation computation.

The most comprehensive courses normally offered by contractors in radiation protection were the *advanced general* courses provided to train the health physicist, industrial hygienists, monitors and others whose full-time job is radiation protection. Also included in this category are the numerous short seminars and conferences designed to keep the professional radiation protection experts current on local or other developments. An example of training in this category given to employees of a laboratory was a series of Health Physics Seminars. These included lectures presented by Health Physics Department employees and guest speakers and discussion sessions of general safety, biological effects of radiation, analysis of exposure standards, health physics instrumentation and legal aspects of radiation injury.

Approximately 6,900 employees attended training courses beyond the basic general level conducted by AEC contractors during 1957 (total employment of the contractors included in the survey was approximately *78,000*). Our review did not assemble data as to the total number of employees receiving the basic general courses. These courses are given more or less routinely to all new employees and in some instances repeated as deemed desirable for old employees. The review did, however, include reports on 16,840 persons' attendance at such courses, a number well below the actual total attendance.

As indicated above the greatest majority of training activity was in the *basic general* category. Sixty-two courses reviewed were of this type. *Basic specific* training accounted for twenty-six courses given to 4,400 employees while 1,100 employees were trained in a total of 21 *advanced general* courses. *Advanced specific* training was given to 660 employees in 30 courses. These statistics can be summarized as follows:

Course level	Scope	Number of employees trained	Number of courses
Basic	General	?	62
	Specific	4,400	26
Advanced	General	1,100	21
	Specific	660	30
Total			139

The great majority of training programs in radiation protection is the responsibility of a full-time professional health protection unit or specialist. These units may have such titles as "Industrial Hygiene Division," "Radiation Safety Division," "Health Physics Depart-

ment," "Safety Department," etc. These organizational units or specialists are also the ones who actually conduct the training.

In some instances, line supervisors are given the responsibility to train their employees in radiation protection. Normally these supervisors can call on health physics specialists to conduct the training for them.

Section 2. Programs Conducted by AEC for Its Own Employees

As indicated above a small percentage of AEC employees have duties requiring them to work in the presence of radiation. By and large the employees in this category are engaged in some aspect of fire protection, police protection, courier or monitoring activities. The Commission's responsibility for providing such services necessarily entails the responsibility for training.

Radiation protection training is given as part of the overall training of new firemen. The scope is generally broad, encompassing at a basic level, radiation and its effects. Each course is then tailored to suit the needs of the participants both in level and subject matter. For example, firefighters at the Idaho Operations Office and Los Alamos, N. Mex., are taught, as a part of their basic indoctrination, how to deal with the hazards of fighting fires where radiation may be present. In addition, for the past several years, the AEC has used the facilities of the Naval Structural Fire Fighting Schools at Norfolk, Va., and San Francisco, Calif., to conduct instructor training courses in the fire protection problems of the atomic energy industry. These courses are intended to improve the level of fire protection at AEC-owned facilities. A large portion of the course material is devoted to the relationship of the radiation hazard to the industrial fire protection problem. Approximately 175 key fire protection personnel representing AEC and AEC contractor installations have attended these courses.

The greatest number of AEC employees who participate in radiation protection training are those engaged in plant protection or police activities. For example, security employees at Los Alamos including those who provide police protection services to the community, receive radiation safety instruction as a part of their basic training and refresher courses are given to all members on a routine basis.

The Oak Ridge and Idaho Operations Offices conduct a radiation hazard training course for all guards assigned as couriers to escort shipments of radioactive material. Supervisory personnel are given special training over and above that given to guards.

Health Physics employees assigned monitoring function at Idaho receive, in addition to necessary on-the-job training, specialized courses in such subjects as internal dosimetry and electronic instrumentation.

During calendar year 1957, over 500 AEC employees participated in eleven radiation protection training courses of the sort described above. In most cases the subject of radiation was not given as a separate course but included in comprehensive training programs such as those designed to equip firefighters and policemen for their regular jobs. The duration of the courses varies in length. The comprehensive "basic training" type of program necessarily is longer, sometimes covering several months of lectures, seminars, practical application and on-the-job training. The more specialized courses and those

designed as "refreshers" were considerably shorter, averaging about 6–8 hours per year.

Section 3. Programs Conducted by AEC for Other Than Its Own Employees

The AEC has, since January 1957, conducted training courses for instructor personnel of state and municipal fire and police services. Specific types of problems are discussed. Guidelines are provided to assist these departments in readjusting and applying their normal operating procedures to fighting fires or to carrying out police activities in the presence of radiation sources. The course, which is taught in language suitable for men without formal scientific training, equips the instructor student to carry on a program for his own organization. A number of media are used to keep in touch with those who complete the course and to keep their information up-to-date.

The Commission provides all training materials; the local sponsor provides training facilities. Those nominated to attend the course are selected in close cooperation with the local sponsor. Local sponsors have included state departments of vocational education, state divisions of safety, municipal police departments, municipal fire departments and state universities as well as others.

The courses are generally of three days duration. To date 40 courses have been presented in 22 States, and approximately 1,200 instructors have completed the course.

The AEC also provides assistance in the form of training aids and publications to groups of all kinds interested in radiation protection training. A limited number of publications are available without charge to anyone who requests them and orders for larger quantities are available for sale by the Government Printing Office. A series of slides has also been developed for use in conjunction with the course offered to municipal fire-fighters and is available for sale through commercial sources.

Section 4. AEC Supported Training Programs

SPECIAL FELLOWSHIPS PROGRAM

The Commission offers special graduate fellowships in the field of radiological physics, industrial hygiene, and industrial medicine. Fellowships in radiological physics and industrial hygiene are administered for the Commission by the Oak Ridge Institute of Nuclear Studies, Oak Ridge, Tenn. The industrial medicine fellowships are administered by the University of Rochester Atomic Energy Project, Rochester, N.Y. Since 1955 about eight appointments have been made each year in the industrial hygiene and eight in the industrial medicine programs; since its beginning in 1948, over 400 fellows have studied under the radiological physics program.

The Radiological Physics Program is designed to train college graduates for positions in the profession of radiological physics by providing fundamental knowledge in radiation physics and biophysics, interaction of radiation with matter and living systems, dosimetry, electronics, and instrumentation, some understanding of the principles of permissible exposure and the prevention of undesirable exposure, and an introduction to the legal and public relations aspects

of radiation protection. Rapidly expanding use of nuclear energy and byproducts has created a wide demand for people qualified in the field. Fellows spend an academic year at their assigned university and then go directly to the corresponding Atomic Energy Commission laboratory for three months of practical training. The universities and laboratories in the program are: Vanderbilt University, Nashville, Tenn., and Oak Ridge National Laboratory; University of Rochester and Brookhaven National Laboratory; University of Washington (Seattle) and Hanford Atomic Products Operation; and University of Kansas and Hanford Atomic Products Operation.

The Industrial Hygiene Program is designed to train college graduates not only in the new and complex problems which have resulted from the development of nuclear energy but from other contemporary problems. Atomic Energy Commission installations and the nuclear industry encounter many of the industrial hygiene problems found in other industries and, in addition, deal with a variety of unique problems. The field now includes the study and control both of the more common occupational diseases and of such other environmental factors affecting employee health as radiation, heat, fatigue, and mechanical hazards. The industrial hygienist applies his special knowledge to the identification and control of health hazards associated with plant or laboratory operations. Starting with the raw materials entering the plant, he observes processing and production methods to identify potential hazards. Then, using a variety of methods he determines the level of toxic substances present in the working environment. Finally, with the cooperation of those responsible for the operation, he develops methods to control or eliminate the hazard. Course work varies with the university selected and with the interests and undergraduate preparation of the individual. All fellows are required to take courses in public health and biostatistics; fellows may elect courses dealing with engineering, health physics, toxicology, industrial medicine, and related fields. These courses are offered under the AEC program by the University of Pittsburgh Graduate School of Public Health and the Harvard University School of Public Health; University of Cincinnati, Institute of Industrial Health.

The Industrial Medicine Program consists of an academic year, with lecture and laboratory instruction in the practice of industrial medicine, industrial hygiene, industrial toxicology, nuclear physics, biophysics, biostatistics, and the public health aspects of occupational medicine. This is followed by an in-plant year with assignment to one or more of the medical departments of the major operating plants and laboratories under the direction of the Atomic Energy Commission. In-plant training is given at Oak Ridge; Los Alamos, N. Mex.; Richland, Wash.; and other areas where there are major industrial medical units.

STATE ASSISTANCE PROGRAM

In cooperation with State health authorities, the Commission has provided this past year for qualified state employees engaged in radiological health activity in connection with atomic energy activities in their States to attend courses offered under the Commission's program of training in radiation control. During the fall semester and continuing through the current academic year, four State personnel are attending a course in radiation control at the School of Public Health

of the University of Michigan. The Commission is offering one year courses including in-plant training at one of the Commission's installations where the trainees may participate directly in the daily operations at the plant and gain practical knowledge of radiation control. This program will be expanded during the coming years to include more trainees and additional training centers.

Plans are also being developed, in cooperation with the U.S. Public Health Service for a shorter program for State employees to condense a year's training into two months of intensive coursework and one month of field work. This program is planned to fulfill a demand for a shorter period of training, but it is in no way considered to be a substitute for the longer and more comprehensive training described above.

Section 5. Other Federally Supported Training

The extent of training activity conducted or supported by other Federal agencies on radiation protection and safety is difficult to determine. This is so because the primary objective of a great deal of the non-AEC training is not usually radiation protection, but rather a related subject of which radiation training is only a part. Thus, that portion of any particular course devoted to radiation cannot always be isolated without intensive analysis. This we have not attempted to do.

This is especially true of the military establishments, particularly the training conducted by the Army and the Navy. The efforts of these two departments are directed toward the needs of the military in the conduct of tactical and defensive warfare. Both services conduct extensive radiological warfare courses (in addition to the basic orientation courses for all servicemen) for officers and key noncommissioned officers whose duties contemplate a line or staff responsibility in the field of atomic warfare or the use of atomic energy in the day-to-day conduct of their jobs. An example of this type of training is a course offered by the Army Chemical Corps to train officers of all services in chemical, biological, and radiological warfare and a course offered by the Navy to train personnel who will be serving as crew members of nuclear-powered ships. The Department of the Army, Corps of Engineers, also offers radiation protection training to enlisted men of all services who participate in the 48 week Nuclear Power Plant Operator's Course.

In addition to these military courses, the Office of Civil and Defense Mobilization conducts training in defense against atomic attack. The substance of this training, however, is not orientated towards the problems of radiation in industry but rather towards the problems the general populace would face in a civil defense emergency. In this sense it is similar to the training given by the military services and therefore not covered in this report.

As indicated above, non-AEC training in radiation hazards and radiation protection is varied and in many cases, the subject of radiation is only a part of a more comprehensive program. The activities covered below are, therefore, not intended as a complete survey of all training, but merely a review of those activities which are related to the industrial, environmental, or operational problems experienced by AEC and its contractors or in which the AEC has a direct interest, such as the licensing program.

DEPARTMENT OF LABOR

The Bureau of Labor Standards, U.S. Department of Labor, has developed a training course in radiation fundamentals. This course will be offered to the State Departments of Labor for the purpose of indoctrinating State factory inspectors. This is an elementary course stressing basic concepts of atomic structure, radiation uses and control measures. It is not designed to qualify State factory inspectors as health physicists or radiological technicians. It is designed to give the State factory inspector an appreciation of the problems. The amount of activity by the Department in this area will be limited due to staff limitations. A pilot course has been conducted, however, for the factory inspectors of one State and plans are now being made to present the course to several other State factory inspector groups.

DEPARTMENT OF COMMERCE

The Maritime Administration of the U.S. Department of Commerce offers courses designed to familiarize Merchant Marine personnel with the problems of radiation. One course conducted by Naval personnel, at Naval installations, is given to licensed officers of the active American Merchant Marine and is designed to train these officers in firefighting and damage control as related to atomic, biological, and chemical defenses. This same course is also given to cadet students at the U.S. Merchant Marine Academy. Another course offered by the Maritime Administration is a full time, 15 month course, in all aspects of radiation given to 16 prospective officers of the N.S. *Savannah*, the first U.S. nuclear-powered merchant ship. By 1960 the balance of the ship's crew (100 members) will have received approximately 40 hours of radiation-health physics training.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

The Department of Health, Education, and Welfare conducts extensive training activities at the Robert A. Taft Sanitary Engineering Center (RATSEC) in Cincinnati, Ohio. Most of the radiological health training is implemented through the resident and field courses conducted by the staff of that institution.

During fiscal year 1958, fifteen course sessions were presented at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio, in basic radiological health, occupational radiation protection, detection and control of radioactive pollutants in air and water, sanitary engineering aspects of nuclear energy, environmental health aspects of nuclear reactor operations, radiological defense monitoring, and radiation protection aspects of tuberculosis X-ray case finding.

Among the 351 trainees in attendance were a large number of the leading scientific personnel in radiological health work, including personnel from operations offices of the AEC, several of the AEC National Laboratories, key health staff members from industrial groups constructing power reactors, active and reserve personnel of the Army, Navy and Air Force, personnel from other Federal agencies, civil defense groups, State and local health agencies and radiological health personnel from foreign countries.

In addition, radiological health training has been incorporated into other courses in water, air, milk, and food fields, presented at SEC.

About 10 percent of the total course time is devoted to brief coverage of the radiological health aspects in these specific fields. The Radiological Health Training staff assists in these other training program areas by preparing training materials and conducting lectures. Twelve course sessions were also presented in the field, with 766 trainees in attendance. Two courses, held in Oregon and California, were presented for State agencies, and one special orientation course was developed and presented in Washington, D.C.

In addition to the regular programs of RATSEC, fiscal year 1959 plans include a number of seminars devoted to the medical aspects of radiological health.

PART VI

RADIATION EXPOSURE, INJURY, AND COMPENSATION

Introduction

In this final part of the report, sections 1 and 2 attempt to relate radiation exposure and its associated problems to workmen's compensation laws and their administration. In addition, two of the Commission's consultants in the field of biology and medicine have prepared papers presenting their views on the subject. These are included in appendix D.

Section 3—prepared especially for this report by the Bureau of Labor Standards, of the U.S. Department of Labor—provides a comprehensive and detailed analysis of the workmen's compensation laws as they relate to radiation injuries. Section 4 discusses the measures which the Commission has found it appropriate to take to overcome—insofar as its contractors' operations are concerned—some of the principal statutory deficiencies in State laws discussed in detail in section 3.

Section 5 summarizes the injury compensation and overexposure experiences of the Commission in its contract operations; and section 6 summarizes data that under existing regulations are reported to the Commission concerning personnel exposures occurring in licensee operations.

Section 1. Problems of Workmen's Compensation Related to Radiation Hazards

INTRODUCTION

Interest in questions of possible effects of radiation exposure on health of occupational workers has raised a number of questions regarding the adequacy of existing provisions for compensation of workers in cases of injury or disease which might arise from occupational exposure to radiation. Some of these questions appear at first sight to be peculiar to the hazards of work with radiation, while others are obviously basic to much broader considerations.

It would appear axiomatic that any proposal for incorporation of any specific provision in existing workmen's compensation programs should be judged against the broad intent of the overall compensation program. It follows that the first step in determining the extent to

which existing provisions for workmen's compensation may be deficient in the field of radiation protection is to consider and to agree, in so far as is possible, what are or should be the objectives of workmen's compensation in the general field of health and disease. However, as will be demonstrated in the following discussion, any realistic statement of objectives must take into account limitations in one's ability to relate specific cases of many diseases to specific causes or origins.

Like many legal codes dealing with social and economic relationships, workmen's compensation in the United States is an organic structure which has been shaped not only by revisions of the written law, but by interpretation and administrative practice. Because workmen's compensation programs are provided and administered at the state level, there is considerable variation in provisions and practices from one state to another. Generally, however, similarities of program are more pronounced than are differences.

Independently of any consideration of occupational exposure to radiation, the present state of development of workmen's compensation involves administrative and technical difficulties which are inherent in the relationship between the health of man and his total environment. Because these problems involve elements which are more familiar than their counterparts in the field of radiation hazards, it will be helpful to consider first in some detail certain general and nonradioactive aspects of workmen's compensation. In this way it is hoped that consideration of any problems of workmen's compensation which are peculiar to radiation hazards can be greatly simplified by isolating these from the problems common to other areas of health and disease.

GENERAL ASPECTS OF WORKMEN'S COMPENSATION

One approach to an understanding of workmen's compensation in the United States is through a review of its historical development. Until the beginning of the 20th century there were no laws dealing specifically with the question of compensation of an employee for any type of injury resulting from or associated with his employment. It is fair to say prior to that time any normal occupational risk was considered to be assumed by the employee and covered by the wage which he received. The first law providing specifically for compensation of workers in the case of occupational injury was adopted by the Federal Government in 1908 and applied to Federal Civil Service employees. Three years later 10 states enacted workmen's compensation laws.

Early legislation and interpretation were primarily concerned with compensating the employee for injury in which the employer could be show to be "at fault." Generally, such provisions did not cover injury due to negligence either of the injured employee or of a fellow employee. With due allowance for variations among various States, it may be observed that coverage and interpretation of workmen's compensation laws have evolved more or less chronologically through the following steps:

(*a*) Provision of compensation when employer was shown to be at fault.

(*b*) Provision of compensation when fellow employee was shown to be at fault.

(*c*) Provision of compensation in cases of injury in which no one was found to be at fault.

(*d*) Provision of compensation in cases of injury involving negligence on the part of the injured employee.

(*e*) Provision of compensation for disease (e.g., silicosis) directly attributable to conditions of work.

(*f*) Provision of compensation for diseases of which the severity was related to or aggravated by conditions of work.

Through the steps enumerated above, workmen's compensation has, in the majority of the states clearly evolved from the position of protecting the workman from fault or negligence on the part of his employer in failing to provide "safe" working conditions to the position of providing insurance against all occupational hazards. A number of factors, some of which are discussed below, account for pressure for continuing evolution through the following step:

(*g*) Provision for compensation of any "occupationally connected" injury, disease or disability, including cases in which the occupational connection may involve only the *possibility* that a disease may have been caused or aggravated by conditions of work.

Administration of a workmen's compensation program involving either of the provisions designated (*f*) and (*g*) above, involves a basic difficulty inherent in the nature of health and disease. This is the problem of determining whether or not a particular illness or disability is in any way connected with the worker's occupational experience. For example, in a situation in which an individual is incapacitated by or dies of a heart disease, although his employment may have involved no known physical or mental strain of unusual severity, application for compensation may be made on the grounds that even the normal activities and tensions of employment may have contributed to the disease. Since, in such a case, it is impossible for a physician to determine whether or not the disease resulted from or was aggravated by conditions of work, the compensation board considering the case must either take the risk of failure to compensate the workman for injury arising from his work by denying the claim or take the risk of paying the workman for an injury which did not occur in connection with his employment.

Not only do workmen's compensation laws generally provide broad administrative discretion but they may specifically provide that the worker shall be given the benefit of doubt. Application of this principle to a case such as that discussed above provides a strong pressure for the administrative agency to award compensation in the event of any injury or disease to which the worker's employment might conceivably have contributed. However, unless this interpretation is specifically provided by law, provisions such as (*f*) and (*g*) above, provide a situation in which the adjudication of the claim frequently cannot be based upon fact, but is decided on the basis of the personal reactions of the adjudicators. Provisions of this sort are basically unsound and unjust to employees, since they do not provide uniform disposition of claims.

The difficulties discussed above are more serious than they may appear to be at first sight. The factors involved in health and disease are sufficiently complex that it is essentially impossible to

state categorically that any disease or illness could not have been influenced by one's occupational history. Certainly such diseases as ulcers, psychosomatic disturbances and mental illnesses could not be excluded. Contagious and infectious diseases, such as polio or tuberculosis would be included because the worker's opportunity to pick up such diseases may occur on the job.

Respiratory ailments in general may be included on the theory that one cannot be certain that some occupational factor, known or unknown, has not contributed directly by irritation of the respiratory system or indirectly by reducing the worker's natural resistance to disease. In fact, with the continuous introduction of new factors into the occupational environment—new materials possibly involving unknown degrees of toxicity, more complex working conditions involving new nervous stresses, greater specialization altering patterns of physical activity—it is generally impossible to say categorically that disease in any employee may not have been undesirably influenced by his occupational environment.

DISCUSSION OF ALTERNATIVE APPROACHES

If we accept the fact that workmen's compensation laws and practices in many states are basically unsound because they provide compensation for diseases under conditions which cannot be identified by medical science, our next step is to consider possible alternative provisions. Only two alternatives relatively free of these difficulties are apparent. One of these is to return to the position of providing compensation only for those diseases, such as silicons, lead poisoning, etc., which can with a high degree of confidence be determined to be of occupational origin. However, since a return to this stage in the evolution of workmen's compensation would be contrary to modern social trends, any proposal to adopt this alternative is unlikely to meet with favor.

A second alternative, one which would completely eliminate the administrative problem of determining whether or not the disability is occupationally connected, is to provide automatic compensation for all diseases, regardless of origin. In effect, such an extension of the coverage specifically provided in workmen's compensation laws would, in addition to providing compensation for all injury, disease and disability of occupational origin, provide the workman with health insurance covering *all* diseases and disabilities *not* occupationally connected. A logical and equitable extension of such a provision would be, of course, to provide the same coverage of disease and disability to persons who do not currently come under the provisions of workmen's compensation; that is, to members of the population at large. While this alternative may be in the direction of social trends, it is perhaps too advanced to receive acceptance at the present time. Assuming strong objections to either of the alternatives discussed above, the possibility of other more acceptable alternatives need to be explored.

Because of the nature of health and disease, any effort to provide compensation for occupationally connected disease without providing benefits for nonoccupationally connected diseases is a compromise. Between the two alternatives discussed above, various degrees of compromise are possible. The discussion here is limited to a very few possibilities which may be applicable to the more specific subject of compensation for radiation injury.

While for many types of disease it is generally impossible for a physician to determine with certainty whether or not a particular case of the disease may be occupationally connected, he may frequently be able to make some estimate of the probability that a particular case is occupationally connected. Intuitively one may feel that if there were a high probability that the occurrence or severity of the disease were due to occupational conditions compensation would be justified; whereas if there were a low probability of any connection with occupational conditions compensation could not be justified. The ability of compensation boards to arrive at equitable disposition of claims of this nature would be enhanced if the law provided specific guidance. For example, the board might be directed to grant compensation in those cases in which it found that the probability of occupational cause is greater than 50 percent, 25 percent, or any other amount which the law might specify. To be meaningful, specific guidance of this sort would require deletion of any qualitative provision that the worker be given the benefit of doubt. In effect, the use of any number less than 50 percent in specifying the probability considered to justify compensation is a statement of the degree to which the worker is to be given the benefit of doubt.

The suggestion made in the preceding paragraph assumes that the compensation board with the aid of appropriate consultants can estimate with some degree of reliability the probability that a particular case of disease or disability is occupationally connected. In a particular case, this may or may not be true. To the extent that the estimate of one expert or group of experts may differ from that of another, this approach to the problem will still fall short of one of the objectives of a satisfactory compensation program—uniform disposition of claims. For certain types of cases, it is possible to substitute to some extent the collective judgment of persons expert in various fields of occupational health and disease for that of individual compensation boards or their consultants. These are the cases involving those phases of occupational health for which there exist accepted guides and standards—the guides which form the basis for industrial hygiene.

To define more clearly the relationships involved, it may be observed that the standards of industrial hygiene are intended to reduce hazards to the worker from exposure to toxic materials and to poor environmental conditions, such as extremes of temperature and humidity, excessive noise, poor ventilation, improper lighting, etc., to levels which are small in comparison with those hazards of everyday life commonly accepted by the average individual on a more or less voluntary basis—hazards encountered in the home, in recreational activities, and in daily movement from one activity to another. Whether or not any particular standard of industrial hygiene entirely eliminates the hazard which it is designed to control is a question which generally cannot be answered. If large quantities of a certain material taken into the body are found to be injurious, how can one be certain that smaller quantities, even though they produce no directly observable effects in large numbers of individuals, do not produce injury too small to detect? However, from the point of view of workmen's compensation, if one is seeking a compromise between a position in which only diseases which can be definitely diagnosed as of occupational origin are subject to compensation and one in which all diseases

and disabilities, regardless of origin, are subject to compensation, the standards of industrial hygiene may provide a basis for such a compromise in certain areas of occupational health. For example, it is known that chronic exposure to high concentrations of benzol or benzene are likely to produce aplastic anemia, frequently leading to leukemia. Let us suppose that an individual, whose occupational duties have involved exposure from time to time to small concentrations of benzene, has contracted leukemia and made claim for compensation on the basis of occupational connection. It is well known that leukemia is a disease which occurs from other causes than exposure to benzene. If investigation of the case shows that concentrations to which the worker has been exposed have not exceeded the currently accepted industrial hygiene guide of 35 parts per million of air, the compensation board may be justified in concluding that it is unlikely that this particular case of leukemia was, in fact, a result of occupational exposure to benzene. Inasmuch as the effects of a particular hazardous material may be highly dependent upon both maximum transient exposures and cumulative or chronic exposures, the formulation and interpretation of such provisions require the services of persons well informed in the field of industrial diseases.

To avoid any possibility of misunderstanding at this point, it is not implied in the preceding discussion that one can in general determine by the use of industrial hygiene standards whether or not a particular case of a disease may have resulted from occupational conditions. The discussion does assume that if occupational conditions have conformed to the intent of industrial hygiene standards, insofar as they apply to the disease in question, the probability of a particular case of the disease having resulted from occupational conditions is sufficiently low that it may provide an equitable basis for limiting workmen's compensation short of complete coverage of disease and disability from all causes.

Section 2. Applications of Workmen's Compensation Principles to Radiation Hazards

INTRODUCTION

For the most part, the problems of application of workmen's compensation to possible diseases resulting from occupational exposure to radiation are similar to those discussed in section 1 in connection with certain types of heart disease and other diseases not specific to occupational factors. It is possible as the result of an accident for a workman to receive sufficient exposure to radiation to die as an immediate result. Within the past 15 years, two persons in the United States have died as the direct result of accidental massive exposure, and in November of 1958, one person was reported to have died as the direct result of accidental exposure to radiation in Yugoslavia. Cases such as these present no problem from the point of view of workmen's compensation, since they involve no questions as to the cause of death.

During the past 15 years twenty-three other persons in the United States Atomic Energy Program have been accidentally exposed to sufficiently large doses of radiation to justify hospitalization over periods of several days or weeks. As far as can be determined from physical examinations, none of these persons suffered more than

temporary incapacitation except for two cases of lens opacities. Compensation for such incapacitation involves no great difficulties, although there might be some uncertainty in evaluating such factors as temporary sterility and the psychological impact of the attention currently given to such incidents.

In addition to the immediate or early effects of exposure to very large doses of radiation, from which complete recovery may be expected, there exists the possibility of certain long-range effects which, from the point of view of workmen's compensation involve all of the problems characteristic of heart diseases and other diseases not specifically related to occupational hazards, as discussed in section 1. The principal diseases or effects of interest in this connection are: (1) leukemia, (2) aplastic anemia, (3) cancer, (4) reduction in life expectancy, (5) genetic effects in descendants and (6) local effects.

LEUKEMIA

While it is believed that a person who has received a whole body radiation dose of several hundred roentgens and survived has a greater probability of contracting leukemia in subsequent years than if he had not been exposed to the radiation, if he does in fact contract leukemia, it is impossible to determine whether this particular case of leukemia resulted from the radiation or would have occurred in any event.

Data on the occurrence of leukemia among survivors of the bombing of Hiroshima and Nagasaki and among persons given massive X-ray doses in the treatment of ankylosing spondylitis would suggest, according to testimony by E. B. Lewis before the Joint Committee on Atomic Energy,[9] that recovering from an accidental whole body dose of 500 roentgens of radiation would have a resultant risk of about one chance in 1,000 of contracting leukemia during each subsequent year.

By comparison, the risk for persons not exposed to large doses of radiation varies from about one in 40,000 at age 30 to about one in 4,000 at age 70. While the risk of leukemia from an acute radiation dose of 500 roentgens is not great, it would appear that, if leukemia were to develop, for example, at the age of 30, after such an accident involving a whole body radiation dose of this magnitude, the leukemia would most likely be a result of the accident. More quantitatively, if one assumes the relationships proposed by Lewis, the average chance that leukemia at age 30 would have resulted from the accident would be 39 out of 40, while at age 70 it would be three out of four.

In the event of a claim based on a case such as that described above, it may well be expected that a compensation board (if convinced that the quantitative estimates presented here are correct) in giving the claimant the benefit of the doubt would assume that the leukemia was indeed a result of the accident.

In the event of leukemia following accidental exposure of the blood-forming tissues to a much smaller dose of radiation, the difficulty in relating the leukemia to the exposure is a much more difficult one. Not only is the probability of leukemia from large doses of radiation expected to decrease with decrease in the size of the dose, but many persons believe that there are radiation doses below which there is no effect on the probability of leukemia or below which the effectiveness

[9] "The Nature of Radioactive Fallout and Its Effects on Man," hearings before the Joint Committee on Atomic Energy, May 27-June 7, 1957.

drops off much more rapidly than the reduction in dosage. The largest dose below which leukogenic effect might occur is commonly called a threshold dose for the production of leukemia. Other persons, extrapolating from certain genetic observations, have suggested that it may be possible that any dose of radiation, no matter how small, to the blood-forming tissues confers a proportionately small probability of leukemia.

A relationship in which the production of an effect is proportional to the causative agent is commonly called a linear relationship, because a graphical representation of the relationship results in a straight line. Perhaps the strongest argument for a linear relationship between radiation dose to the blood-forming tissues of the body and the resultant probability of leukemia is that given by Prof. E. B. Lewis, "Leukemic and Ionizing Radiation," Science, pages 965 ff., May 17, 1957.[10]

More specifically, the hypothesis supported by Lewis is that any radiation dose to the total blood-forming tissues of the body confers a proportional probability, in each subsequent year of life of leukemia. Taking into consideration available data on increased incidence of leukemia as a result of exposure to large doses of radiation, he estimates the probability to be 2×10^{-6} per roentgen per year. If the hypothesis and the quantitative relationship proposed by Lewis are correct, a person exposed to a whole-body dose of 5 roentgens would result in a probability of one chance in 100,000 of contracting leukemia during each subsequent year. If he lived for thirty years after the exposure occurred, the corresponding probability of his contracting leukemia as a result of this particular exposure would be three chances in ten thousand.

Some of the evidence contrary to a linear relationship between radiation dose and resultant production of leukemia has been summarized by Dr. Austin M. Brues, in an article, "Critique of the Linear Theory of Carcinogenesis."[11] Two of the four conclusions stated by Dr. Brues in his summary are:

"(1) Present data on human leukemogenesis by radiation fail to indicate a linear relation between dose and effect. Because data are scanty, such a hypothesis cannot be ruled out statistically, but it is less probable than a nonlinear or threshold relation.

"(2) Other instances in which carcinogenic agents have been examined from the standpoint of dose and dose-rate relations show many clear instances where the relation is nonlinear and none in which linearity is unquestionably demonstrated."

It is outside the scope of this discussion to debate the relative merits of various hypotheses relating the probability of leukemia and other malignant diseases to irradiation of the tissues involved. Both the article by Lewis and the article by Brues provide extensive references which may be pursued by serious students of the subject. Certain aspects of the subject are, however, of direct interest to the question of workmen's compensation in relation to radiation hazards.

Because it is impossible to determine experimentally whether or not such a threshold exists, many persons take the position that to be on the safe side in establishing standards of radiation protection we must

[10] This article and oral testimony on the subject are given on pp. 955–977, pt. 1 of the hearings on "The Nature of Radioactive Fallout and Its Effects on Man" cited above.

[11] Science, pp. 603–609, September 26, 1958.

assume the worst; that is, that even small doses of radiation produce proportionate increases in the chance of leukemia. However, in estimating the actual probability that a particular case of leukemia resulted from a given small dose of radiation, this serves only to give an approximate maximum value of such probability. The actual probability may be less or, depending upon the existence of threshold above the dose under consideration, zero. With these limitations in mind, the hypothesis of linear relationship is used in the following discussion to illustrate the range of relationships which might conceivably be involved in trying to judge whether or not a particular case of leukemia may have resulted from exposure to radiation.

Current standards for protection against excessive exposure to radiation limit occupational averages to five roentgens per year. If Prof. Lewis were correct in assuming that each roentgen of radiation dose to the blood-forming tissues confers a probability of leukemia of 2×10^{-6} per roentgen per year, this would result in three chances in 100,000 of leukemia during the second year, five chances in 100,000 during the third year, etc. The following table compares the increase in risk, calculated on the basis of this hypothesis, from exposure at the maximum permissible rate from age 20 to age 65, with the average risk to persons with no unusual exposure to radiation.

Age	21	30	40	50	65
Normal risk, per year	20/1,000,000	26/1,000,000	34/1,000,000	68/1,000,000	200/1,000,000
Additional risk from 5 roentgens per year after age 20	3/1,000,000	19/1,000,000	39/1,000,000	59/1,000,000	88/1,000,000

In addition to the fact that the actual additional risk may be much less than the "maximum" computed in the bottom row of the table for persons exposed continuously at the maximum permissible average rate, it may be improbable that many persons would be exposed at this average rate over a period as long as 45 years.

The foregoing discussion suggests that for persons working within current standards of radiation protection, the risk of leukemia from exposure to radiation is, at worst, generally less than the risk of leukemia from other sources. How much less it is in fact, we have no means of estimating. Qualitatively, at least, from the point of view of workmen's compensation, the situation is no different than that of heart disease or other diseases discussed in connection with the more general problems of workmen's compensation in the field of health and disease. Like heart disease, the probability of leukemia from natural causes and, perhaps, from continued exposure to radiation under routine conditions is relatively small at the age of 20 or 30, but increases sharply with advancing age. If there are any important differences in the two diseases from the point of view of workmen's compensation, they are not readily apparent.

CANCER AND APLASTIC ANEMIA

Qualitatively the considerations discussed above in connection with leukemia are considered to apply as well to cancer and aplastic anemia. We do not know of any important differences in possible relationships

between exposure to radiation and incidence of these diseases which require consideration different from that given to leukemia.

In further development of the thesis that the occupational hazards associated with radiation do not present unique problems with respect to workmen's compensation, it may be observed that leukemia and other malignant diseases are not only of common occurrence in man but may be produced by occupational conditions other than exposure to radiation. For example, it has been observed above that excessive exposure to benzene may result in aplastic anemia, frequently leading to leukemia. Many hydrocarbons and other organic compounds are known to be carcinogenic or to contribute to carcinogenesis under certain conditions. Undoubtedly there are many other carcinogenic agents and conditions as yet undiscovered.

REDUCTION IN LIFE EXPECTANCY

Observations on experimental animals have shown a reduction in life expectancy from large doses of radiation in addition to that resulting from increased risk of the specific diseases, leukemia, cancer, and aplastic anemia. Efforts to observe corresponding effects from small doses of radiation have been inconclusive. Nevertheless, there has been suggested the possibility that small doses of radiation reduce life expectancy by amounts proportional to the dose. Because observed reductions for given doses vary from one species of animal to another, there are further uncertainties in extrapolating these relationships to man. Such extrapolations have led to suggestions that occupational exposures to radiation might lead to reductions in life expectancy in the range from one to fifteen days per roentgen of dose.

Reduction of life expectancy as a result of routine occupational exposure, if it occurs, is expected to be a statistical result which could be expressed quantitatively only in relation to a relatively large group of persons. Statistically, members of the group would be expected to die of the same diseases as if the reduction had not occurred. At the death of any one person, it would be impossible to determine whether or not he had, in fact died at an earlier time than if the reduction in life expectancy of the group had not occurred. Provision of compensation for possible reduction in life expectancy would appear to fall outside the scope of workmen's compensation as currently practiced.

GENETIC EFFECTS

The last biological effect of radiation to be given specific consideration in the present discussion is that of possible genetic effects upon descendants of the exposed persons. It is estimated that about two percent of live births in the United States involve observable genetic defects of one kind or another. These are considered to be the result of a normal rate of genetic mutation over past generations.

It is further estimated by geneticists that if the total population were to receive an average radiation dose to the gonads of 50 roentgens per generation, the present rate of mutation would be about two times as great. In terms of genetic risk to the children of persons working with radiation this may be interpreted as follows. Of the genetic defects which will result from the mutations produced in any one generation, about 10 percent are expected to occur in the next gen-

eration. If only one parent is exposed to the radiation, the probability of a resultant genetic effect in offspring of the next generation is about half as great as if both parents were exposed. Thus, if one parent were to receive a gonadal dose of 50 roentgens, the probability that any child born from a subsequent conception would display an observable genetic defect as a result of such an exposure is

$$1/2 \times 1/10 \times 2\% = 0.1\% = 1/1{,}000$$

If, following a total gonadal dose of 50 roentgens to the parent during his preceding life, a child were born with a genetic defect, the consequent probability that the genetic defect arose from the exposure to radiation rather than from normal genetic mutation would be only one chance in twenty.

From the point of view of workmen's compensation, it is obviously impossible to provide compensation for those cases of genetic injury which affect the worker through defects in his children without providing compensation for the much larger number of cases resulting from normal rates of genetic mutation.

In addition to observable genetic defects in live births, genetic mutations are expected to result in increased frequency of embryonic and neonatal deaths, stillbirths, and childhood deaths. A discussion of these effects is contained in statements by Prof. James Crow, pages 1020–1024, part 2, of the hearings on "The Nature of Radioactive Fallout and Its Effects on Man," cited above. According to the table given on page 1021 of those hearings, a gonadal dose of 50 roentgens to one parent would be estimated to increase the frequency of such effects by about 3 percent of the normal frequency. This is equivalent to saying that if, for example, a stillbirth followed the exposure of a parent to a gonadal dose of 50 roentgens, the chance of its being a result of the exposure would be about one in thirty.

EFFECTS OF LOCALIZED EXPOSURE

The exposure of a limited portion of the body to large doses of radiation may result in one of the effects discussed in the preceding paragraphs—effects which are not peculiar to ionizing radiation. However, there are a number of effects of localized exposure to ionizing radiation that may be diagnosed with reasonable confidence as resulting from such exposure. An example is the radiation cataract of the eye which is characteristically different from senile cataracts. Such cataracts resulting from ionizing radiation are not distinguishable by examination from cataracts resulting from excessive exposure to such nonionizing radiations as infrared (heat rays) and microwaves (ultrahigh frequency radio or radar). Other examples of effects of localized exposure are gross changes which take place in the structure of heavily irradiated tissues, such as the skin of the hands, in the case of exposure of the hands, and in certain bones as in the case of radium dial painters.

PRESENT STATUS OF KNOWLEDGE OF BIOLOGICAL EFFECTS OF RADIATION

The numerical illustrations given above in connection with discussions of various biological effects of radiation are subject to uncer-

tainties of which some may be quite large. Statements that such uncertainties exist are frequently taken to mean that very little is known about the biological effects of radiation. While studies of such effects continue to open up new avenues of investigation—creating, as does research in other fields of science, more questions than answers—when compared with the state of our knowledge in some other field of human health, we are relatively well informed on the biological effects of radiation. Through intensive research, we are increasing our knowledge of the relationships between radiation and health at a rapid rate. From the point of view of workmen's compensation, this means that the health standards used to limit hazards from radiation have at least as firm a basis as those generally used in other phases of industrial hygiene.

SUMMARY AND CONCLUSIONS

In the preceding discussion, it has been pointed out that:

(1) It is impossible for a workmen's compensation program to provide compensation for all cases of occupationally connected disease or disability without also providing compensation for nonoccupationally connected cases of disease or disability in several major classes of disease. The inability of medical science to determine whether or not a particular case of such diseases is occupationally connected is more probably a basic characteristic of health and disease than a shortcoming of medical science.

(2) Examination of the principal diseases which are known to be producible by exposure to large doses of radiation does not disclose any hazards from exposure to radiation which are known to be unique in the field of occupational health. As a special case, it is known that other materials and conditions frequently encountered in industry can produce malignant diseases, and it appears probable that there are many carcinogenic materials in industry which have not been identified.

SECTION 3. ANALYSIS OF WORKMEN'S COMPENSATION LAWS [12] IN RELATION TO RADIATION INJURIES

INTRODUCTION

The purpose of this analysis of workmen's compensation laws is to show the extent to which radiation injuries are covered under such laws at the present time. It also will highlight some of the many problems anticipated in providing full workmen's compensation protection for workers in the event of injury due to a radiation hazard.

Workmen's compensation laws are in effect in all States, the District of Columbia, Hawaii, and Puerto Rico. In addition to these 52 laws, there are two Federal laws, the Federal Employees' Compensation Act and the Longshoremen's and Harbor Workers' Compensation Act.

The laws vary both in standard and in administrative procedures. It is not possible, therefore, to compare the various acts as a whole. Comparisons in this report are limited to basic provisions of the law and do not include information on judicial decisions or administrative rules and regulations.

[12] This section has been prepared by the Bureau of Labor Standards, U.S. Department of Labor.

Among the specific provisions analyzed in this report are those relating to whether the law is compulsory or elective, the methods of insurance, the employments covered and those specifically exempted, numerical exemptions, extraterritorial coverage, accidental injuries and occupational diseases, subsequent injury funds, waivers, time limits for filing claims, and indemnity, medical and rehabilitation benefits.

In general, the report shows that very few of the State laws provide full workmen's compensation protection for workers who are exposed to radiation hazards. One of the major gaps is the time limit for filing claims. Almost all the laws fail to recognize the latent nature of radiation diseases with the result that the time limit for filing claims may expire before the worker knows that he has suffered a radiation injury due to his job. About one-third of the laws have inadequate or no coverage for radiation diseases. Limitations on medical benefits for radiation injuries apply in about one-third of the laws. Very few of the jurisdictions provide for supervision of medical care. Less than half of the laws contain any provision on rehabilitation. Only one-third of the laws include radiation injuries in the coverage of the subsequent injury funds.

TYPE OF LAWS

The workmen's compensation laws of the States, Territories, and Federal government may be classified as compulsory or elective.

A compulsory law requires every employer within the coverage of the act to accept its provisions and to provide for the benefits prescribed by the act. Twenty-nine of the 54 workmen's compensation laws in this country are compulsory.

An elective law permits the employer and employee to accept or to reject the provisions of the law. Under most types of elective laws, acceptance of the act by the employers or employees is presumed unless specific notice of rejection is filed. In case the employer rejects the law, he loses the customary common law defenses of assumed risk of employment, negligence of fellow servants, and contributory negligence. If the employee rejects the act but the employer accepts it, then the employer is allowed to use the common law defenses in case of a suit by the employee for damages. If an employer has rejected the act his employees may be unable to obtain compensation unless they sue for damages regardless of whether or not they have accepted the act. (See appendix E–1 for list of compulsory and elective laws.)

The first test, therefore, of whether a workmen's compensation law covers a radiation injury is the type of law. If elective, the injury may or may not be covered.

SECURITY FOR PAYMENT OF BENEFITS

There are three types of provisions to assure payment by the employer of compensation indemnity benefits or medical and related benefits in the event of a radiation injury. These methods are: (1) to insure with an authorized private insurance company; (2) to give proof of his qualifications for self-insurance; and (3) to insure with a State fund. Since radiation injuries can involve costly workmen's compensation payments, it is important to assure a sound method of financing such costs.

Under all but nine of the laws, employers can obtain insurance through private insurance carriers. Employers may qualify as self-insurers under all but eight of the laws. Where self-insurance is permitted, the self-insurer must meet certain conditions such as bonding, posting of securities, or other proof of financial ability to carry his own risk.

State funds are provided for in 19 of the jurisdictions. These funds are classified as "exclusive" or "competitive." Under an exclusive State fund, employers are required to insure in the fund. If a jurisdiction permits an employer to insure with either the State fund or a private insurance company the fund is referred to as a competitive State fund. Eight jurisdictions have exclusive State funds and eleven are classified as competitive State funds. Two of the exclusive State funds also permit self-insurance. The Federal Employees' Compensation Act depends on direct appropriations by Congress for the payment of all benefits.

The type of insurance provision in each jurisdiction is shown in appendix E–2.

EMPLOYMENTS COVERED AND EXCEPTED—PRIVATE EMPLOYMENT

No workmen's compensation law covers all private employments. Every law excludes some specifically named classes of employees. Many laws exempt employers who have fewer than a certain number of employees, and other laws cover only hazardous, extrahazardous, or especially dangerous occupations. These gaps in coverage may mean that a worker suffering a radiation injury is without workmen's compensation. In most States, the employments exempted may be brought under the law through the voluntary acceptance of coverage by the employer.

Excepted employments

Farm and domestic workers are generally excluded from workmen's compensation laws. Railroad and maritime workers are also exempt. Many laws also contain a list of other excluded employments ranging from two in one State to 18 in another State.

Hazardous employments

In 13 jurisdictions (Illinois, Kansas, Louisiana, Maryland, Massachusetts, Montana, New Mexico, New York, North Dakota, Oklahoma, Oregon, Washington, and Wyoming), the laws apply to listed "hazardous" or "extrahazardous" employments. The use of such terms was an expedient adopted in the early days of workmen's compensation legislation to meet the risk that the broad coverage type of law might be held unconstitutional by the courts. Now the constitutionality of workmen's compensation laws has long been assured, and the retention of this provision in some State laws is a major obstacle to comprehensive coverage of workers. In a few of these States, the list of hazardous industries is comprehensive. However, difficulties of interpretation arise where the laws contain both specific and general provisions. For example, one State specifies certain "extrahazardous" employments that are covered and in addition states that the act shall apply to all extrahazardous employments not specifically enumerated and to all work of an extrahazardous nature. Regardless of this general provision, it has been found

necessary to amend the law from time to time by adding to the list of specific extrahazardous employments.

Numerical exemptions

The laws of 25 jurisdictions contain no provision for an exemption based on number of workers employed. The other 29 jurisdictions exempt employers who have fewer than a stipulated number of employees, ranging from less than 15 in one State to less than two. (See appendix E–3 for list of States with no numerical exemptions and those with such exemptions.)

EMPLOYMENTS COVERED AND EXCEPTED—PUBLIC EMPLOYMENTS

Workmen's compensation laws for public employees are more frequently compulsory than are those dealing with private employees. Forty-four jurisdictions have laws that are compulsory at least as to some public employees. In the remaining ten jurisdictions coverage of public employees depends entirely upon the election of the State, city, or other political subdivision, or agency to bring employees under the act (Connecticut, Delaware, Florida, Kansas, Kentucky, Mississippi, Missouri, New Hampshire, New Mexico, and Tennessee).

EMPLOYMENT COVERED AND EXCEPTED—EXTRATERRITORIAL COVERAGE

The extent of coverage of radiation injuries is also affected by the extraterritorial provisions of the various workmen's compensation laws. When an employee hired in one State is injured in another, sometimes it is clear that he is covered by the law of the State where he was hired; sometimes such coverage is doubtful, depending upon a number of factors. On the other hand, sometimes the employee is specifically covered by the law of the State where the injury occurred. In many instances it is difficult to determine in what State the remedy should be sought. The difficulty is caused by the varying provisions in the different laws relating to this problem.

Some of the States, including Connecticut, Massachusetts, and Ohio, provide, with no restrictions, that the law covers injuries occurring both inside and outside the State. Others provide that if a contract to work is made in the State, the law will apply in cases of injuries outside the State. Still others—for instance, those of California, Michigan, and Nevada—require that the employee's regular place of employment, or the employee's residence, or both, also be in the State where the contract is made. Some of the laws also require that the accident must occur within a certain time after leaving the State; for instance, Texas sets one year, and Colorado and Utah set 6 months. Delaware and Pennsylvania specify that the work outside the State must not extend beyond a period of 90 days. About one-fourth of the laws omit any reference to extraterritoriality, but the courts of some of these States, for instance New Jersey and New York, have interpreted the law as being applicable to such accidents. In New York the law has been held to apply if the contract of employment was made in the State, or the employment was incidental to a business carried on in the State, while the New Jersey law has been construed to apply generally to accidents suffered on contracts of hire made outside the State.

In some States reciprocal arrangements have been developed to meet this problem. Under these arrangements, the workmen's compensation law may not apply to an employee temporarily within the State if his employer has furnished proof of workmen's compensation coverage under the law of another State and provided that the other State also recognizes the same extraterritorial application for employees temporarily within its borders.

Extraterritorial provisions will affect primarily the coverage of radiation injuries for workers engaged in the servicing, installation, and construction of atomic energy facilities and in the transportation of materials with a radiation hazard where such workers cross State lines in their activities.

INJURIES AND DISEASES COVERED

Accidental injuries

An analysis of the workmen's compensation laws of the various jurisdictions shows that the laws differ not only in the employments that are covered but also in the injuries covered. The compensation laws in general are intended to cover all accidental injuries due to the nature of the employment regardless of who was at fault. The specific definition of accidental injury in the law, however, will determine whether a radiation or other type of injury is covered. A review of the definitions shows that the usual language is to specify that the injury must be an "injury by accident arising out of and in the course of employment." In some laws, only the language "course of employment" is used. The terms "by accident" and "arising out of and in the course of employment" are subject to interpretation in the different States and may limit the coverage of radiation or other injuries. The definition of accidental injury therefore becomes of particular importance in radiation cases.

Sample provisions of definitions of "accidental injury" in the various laws are attached as appendix E–4.

Occupational diseases

Occupational diseases are covered in two ways by the workmen's compensation laws. (See appendix E–5 for list of States covering occupational diseases.) One is by the full coverage method under which all diseases are covered. This is usually done by the definition of "injury" or by definition of "occupational disease." More than half of the laws now provide for full coverage. The other method is by listing specified diseases that are covered and is referred to as "schedule" coverage. A few laws list the specific diseases covered and then include a general provision for coverage of "any and all occupational diseases." The workmen's compensation laws of Tennessee and Virginia permit full coverage at the option of the employer. The laws of Mississippi, Wyoming, and Montana do not have any provision in the law for occupational disease coverage. Five of the laws with schedule coverage do not include radiation diseases.

Eighteen laws include specific language for coverage of radiation diseases. However, in eight of these laws, it is questionable whether the language used is adequate to cover all radiation diseases. (See appendix E–6 for laws with specific language together with language used.)

The International Association of Industrial Accident Boards and Commissions' Atomic Energy Committee Report in 1956 recommended that a uniform language be used and suggested that the term "disease caused by exposure to ionizing radiation" be inserted in the law where considered necessary. New York adopted this language in 1957.

Subsequent injury fund provisions

Workmen's compensation laws constitute one of the obstacles to the employment of handicapped workers because of the fear of employers that they may be assessed a heavy compensation cost if the handicapped worker suffers a subsequent injury. To meet this problem, subsequent injury funds have been established. A subsequent injury fund is a special fund to insure that an employer who hires a handicapped worker will not, in the event such worker suffers a subsequent injury on the job, be responsible for the payment of compensation for a greater disability than that actually resulting from the subsequent injury by itself. Under the New York and Minnesota laws, the employer is only liable for compensation for a maximum of 104 weeks. But the employee is fully compensated. The subsequent injury fund pays the difference between what he actually receives from the employer and what he would have received for the actual disability resulting from the combined injuries.

The coverage of a subsequent injury fund may be broad enough to include any type of prior disability—such as polio, epilepsy, arthritis, heart disease, or diabetes; or it may be so limited that it applies only to such handicaps as the loss, or loss of use, of a hand, arm, foot, leg, or eye. The great majority of these funds are limited in coverage to the loss of a member of the body.

A worker who has suffered a radiation injury may find it difficult to obtain employment where a subsequent injury fund does not cover such injuries. Only 17 of the subsequent injury fund provisions cover radiation injuries at the present time. (See appendix E–7 for a chart showing the subsequent injury fund provisions which cover radiation diseases.)

Waivers

Most jurisdictions prohibit an employee from waiving his rights to compensation. However, early in the history of workmen's compensation, a number of States enacted provisions permitting handicapped workers to "waive" their rights to benefits for an injury caused, or contributed to, by a previous disability. This was done because of the reluctance of employers to hire or keep an employee whose physical condition might create an extra compensation cost if he suffered a further injury on the job.

The development of the subsequent injury fund system has made waiver provisions obsolete. However, some jurisdictions still authorize the use of waivers. A waiver for radiation injuries is permitted under 14 of the laws. (See appendix E–8 for status of waivers under workmen's compensation laws.)

TIME LIMITS FOR FILING CLAIMS

One of the major problems affecting the coverage of radiation injuries under workmen's compensation laws is the requirement relat-

ing to the time limit for filing a claim. Many workmen's compensation laws require that the claim must be filed within a certain period after date of last exposure. Other laws require that the claim be filed within a specified period after disablement regardless of whether the worker knows that his disability was due to his job. Because of the slowly developing nature of radiation diseases, and the difficulty of determining the causal relationship between such diseases and the job, an employee may be unaware that he is suffering from a radiation disease due to his employment and may not suffer disability for many years after his last exposure to radiation. The time limit provision will have, therefore, an important bearing on a worker's right to compensation if he suffers a radiation injury.

The great variation in the time limits for filing claims is shown in appendix E–9 attached. Fifteen States require a claim to be filed within a specified period from date of disablement. In six of these 15 States it is also required that it be filed within a certain period from date of last exposure.

In four States, the time limit is based entirely on date of last exposure, varying from one to three years after such date.

The date of injury is the basis for determining time limit for filing claim in 13 States. In three of these 13 States, the date of last exposure is also included in determining the time limit. The date of injury in occupational disease cases usually is not spelled out in the law. Generally it is a matter for interpretation.

In four States, the date of manifestation of symptoms of an occupational disease constitutes the date from which the time limit begins to run.

The date of worker's knowledge that he has an occupational disease is the test for tolling the time limit in six States (California, Delaware, New Jersey, New York, Washington, and Wisconsin). However, in two of these States (Delaware and New Jersey), the date of last exposure is also used and serves to restrict the time within which the claim must be filed. In two other States, California and New York, both date of worker's knowledge and date of disablement are specified as the requirements for determining when the time limit begins.

It is difficult to evaluate the effect of some of these time limit provisions on coverage of radiation injuries since much depends on the interpretation given to them by the courts. On the basis of the specific provision in the law, however, only the California and New York laws meet the standard recommended by the IAIABC in its Atomic Energy Committee Report for 1956.[13] This report recommends that "the time limitation in filing of claims not begin to run until the date on which the employee has knowledge of the nature of his disability and its relation to his job and until after disablement."

Samples of the various types of provisions mentioned are attached as appendix E–10.

COMPENSATION BENEFITS—MEDICAL BENEFITS

All jurisdictions provide that the injured worker shall receive medical aid. The extent of medical benefits varies from full benefits in most States to limitations in other States as to period of treatment or cost or both. Since radiation injuries may involve extensive medi-

[13] "Workmen's Compensation Problems," Bulletin 192, Bureau of Labor Standards, U.S. Department of Labor, pp. 160–167.

cal care, it is important to know whether the law provides full or limited benefits. (See appendix E–11 for list of States providing full and limited medical benefits.)

Full benefits

Thirty-three jurisdictions provide for full medical benefits for accidental injuries and occupational diseases. In 17 of these 33 laws, it is specifically provided that medical aid must be furnished without limit as to time or amount. In the other 16 laws, the administrative agency is authorized to extend such aid indefinitely beyond any limits expressed in the law.

Limited benefits

Medical benefits are limited in 21 laws. In 14 of these laws the limitations apply to both accidental injuries and occupational diseases. In two of these laws, the medical benefits are limited for all occupational diseases. In the other 5 laws the medical benefits are restricted for silicosis, asbestosis, or other types of dust diseases. In at least 16 jurisdictions, therefore, medical benefits for radiation injuries will be limited.

The limitations on period of treatment range from 91 days to 4 years, and as to amount, from $1,000 to $2,500. In some laws both period and amount are limited.

Choice of physician

In the majority of the jurisdictions the employer is given the right to select the first treating physician or surgeon. The injured worker is given the right of selection in about one-third of the laws. (See appendix E–12 for list of laws showing method of selection of doctor.)

Supervision of medical care

Radiation injury cases may require specialized medical care. It is therefore important to know, in evaluating the medical care provision, whether the workmen's compensation agency has the authority to supervise and control the medical care program. A report of the IAIABC Medical Committee in 1957 indicated that only two jurisdictions approach the IAIABC standard of supervision of medical care.[14] This standard includes the following:

(*a*) one or more physicians on the staff of workmen's compensation agency

(*b*) reports required by the workmen's compensation agency from attending physicians

(*c*) right of workmen's compensation agency to suggest to attending physician the need for change in treatment

(*d*) use of impartial advisory medical panels to supervise medical care.

COMPENSATION BENEFITS—INDEMNITY BENEFITS

The amount of cash benefits payable for a radiation injury under the various workmen's compensation laws is determined by a number of factors and will vary from State to State. Usually the law will specify that the worker is entitled to 66⅔ percent of his average weekly wages. In some States the percentage will vary according to the

[14] "Workmen's Compensation Problems," Bulletin 195, published by the Bureau of Labor Standards, U.S. Department of Labor, pp. 172-173.

marital status of the worker and the number of dependent children. However, the percentage which the worker actually receives is also affected by the maximum weekly rate specified in the law. This rate may result in the worker receiving much less than 66⅔ percent of his average weekly wages. A table showing the ratio of the maximum weekly benefit rate to the State's average weekly wage is attached as appendix E–13. This table shows that only five jurisdictions now provide a benefit rate which will enable most workers to receive at least two-thirds of the State's average weekly wages based on wages of workers covered under unemployment insurance laws in 1957.

Other factors which affect the benefits received by an injured worker are the term or period of payment specified in the law and the aggregate or total maximum amount of payment. The amount may also differ as to type of injury.

The maximum weekly payments vary from State to State. In a few laws, the payments exceed $50 but the most common benefit rate is between $35 and $40.

Twenty-five laws pay benefits for permanent total disability for the entire period of disability. In the other laws, the period for such payments is limited to a specified number of weeks varying from 330 to 550 weeks or the total amount payable is limited, ranging from $7,500 to $20,000. In some jurisdictions, both the period and total amount payable are limited.

The specific benefit rates by jurisdiction for the various types of disability and for death are indicated in appendices E–14 through E–18.

COMPENSATION BENEFITS—REHABILITATION BENEFITS

Less than half of our workmen's compensation laws contain any specific provision on rehabilitation of injured workers. (See appendix E–19 showing States with rehabilitation provisions.) A worker who has suffered excessive radiation exposure may need rehabilitation and retraining for another job. The extent to which he will be entitled to rehabilitation services will be determined by the particular workmen's compensation law involved.

Four States (Ohio, Oregon, Rhode Island, Washington) and Puerto Rico operate rehabilitation centers or facilities under the workmen's compensation program to make available to injured workers the full services necessary to restore their ability to perform a job.

In addition to the workmen's compensation rehabilitation centers mentioned above, eight jurisdictions (Florida, Massachusetts, Minnesota, Missouri, New Jersey, New York, West Virginia, and Hawaii) maintain special rehabilitation divisions or units within the workmen's compensation agency. These units are designed to promote the referral of injured workers to public or private rehabilitation facilities and to study the rehabilitation needs and problems affecting injured workers.

Special maintenance and other benefits for injured workers while undergoing rehabilitation are provided in 18 of the laws. The Arizona law gives the Commission broad authority to provide such awards as may be necessary for the promotion of vocational rehabilitation. Under the Wisconsin law, provision is made for the payment of full compensation for a maximum period of 40 weeks during re-

habilitation training. The actual and necessary costs of maintenance and travel are paid for a maximum period of 40 weeks, if the training is elsewhere than at the place of residence. In addition, for amputees there is no limit on the number of weeks for which full compensation is paid while receiving training in the use of prosthetic devices. The Oregon law provides for benefits of $50 to $100 a month and authorizes the Commission to expend such funds as may be necessary to accomplish rehabilitation. In the other laws providing special maintenance or other compensation for rehabilitation, there is a maximum limit on the amount of compensation, or period of weeks, or both.

CONCLUSION

This brief analysis of workmen's compensation laws points up the wide variation in the provisions of the laws, the gaps in the coverage of radiation injuries, and the need for reexamination of these laws as to changes required to meet the new problems resulting from the growing use of atomic energy for peaceful purposes.

The extent of protection for workers who suffer a radiation injury will depend not only on the law but on its administration. This report does not include a discussion of problems due to difficulties in administration of the law. Problems in administration include insufficient funds resulting in lack of staff and inadequate salaries to attract and retain competent personnel. The use of court administration in five States also constitutes a problem in the administration of these laws. Courts are not organized and equipped to render the type of service needed particularly in regard to supervision of medical care and rehabilitation.

Another problem is the question of proving causal relationship between a radiation injury and the job. As experience develops with specific cases, it may be possible to better determine what types of provisions in workmen's compensation laws will most effectively meet this problem.

Section 4. AEC Requirements To Overcome Deficiencies in State Laws—AEC Contractors

INTRODUCTION

From the beginning of the atomic energy industry—and to the extent authorized by State laws—insurance companies have handled workmen's compensation matters for MED and AEC contractors. The services of these companies have been used to file policies with State authorities as evidence of compliance with applicable laws; to file necessary reports of injury; investigate claims; and to pay or deny and, where necessary, represent their clients in litigations arising out of claims.

In the States of Washington, Nevada, and Ohio, private insurance companies are not permitted to write workmen's compensation insurance. Therefore, in these States AEC contractors obtain coverage through State insurance funds.

BACKGROUND

Early in the MED program, contractors were authorized to establish special benefit plans for their employees on the theory that contract operations would subject employees to serious and unusual hazards concerning which it was impossible to provide adequate protection through normal insurance coverage. These special benefit plans would permit the contractor, with the Government's approval, to pay up to $10,000 if an employee were killed or disabled as a result of certain specified hazards. The particular hazards covered by the plans varied considerably from one contract to another but all included hazards which are to some extent peculiar in kind or degree to the atomic energy industry, such as radiation, explosion resulting from atomic disintegration, and exposure to certain toxic materials.

These plans provided for a maximum payment to any individual employee of $10,000, and also provided for payment of medical expenses as a part of, but not in addition to, this maximum. Payments for injuries not resulting in death were also authorized under these plans. For example, a 50 percent permanent disability might warrant a payment of $5,000 to the injured employee. Payments made under these benefit plans were in addition to any workmen's compensation payments an employee might receive. These plans did not intend to establish for an employee or his beneficiary any legal rights.

Such plans are still in effect for the operations of Carbide at Oak Ridge; Monsanto at Dayton; the University of California at Los Alamos and Berkeley; General Electric at Hanford and Schenectady; the University of Chicago at Argonne; and Columbia University in New York. There is also a limited plan in effect for Associated Universities, Inc., the Commission's contractor at the Brookhaven National Laboratory in Long Island.

REAPPRAISAL AND CURRENT POLICIES

In January 1952 the Commission reexamined the problem of compensation for radiation disabilities of contractor employees in the light of actual experience. It was found that these hazards had not in fact proved too great. Payments under the special benefit plans had been made to or for only eight individuals at that time of which four were radiation cases. However, other potential claims were known to exist. It was also realized that the number of potential claims might increase as a result of the delayed effects of radiation or exposure to toxic materials. Nevertheless, these low figures demonstrated the effectiveness of protective measures.

In line with the Commission's general efforts to give the public a proper perspective of hazards connected with atomic energy, it was believed desirable not to establish a special category of benefit payments for these hazards. There were, however, certain aspects of injuries resulting from hazards associated with atomic energy which it was felt might in a particular case justify special consideration. For this reason, AEC did not propose at that time a complete abandonment of special benefit plans but rather a substantial modification of their use in new contracts. Furthermore, a review of the workmen's compensation and occupational disease laws of the States in

which AEC then conducted its principal operations indicated that some States did not have adequate laws to cover all injuries of special significance in AEC operations.

For example, in a number of States in which AEC operated the coverage was more complete for injuries resulting from sudden accidents than for injuries and diseases resulting from exposure over a period of time. In the latter case the State law not infrequently imposed a limitation on the period within which the employees must file notice or take legal action or within which the disability must occur. Likewise, some States did not permit the reopening of prior compensation determinations in the event of delayed or aggravated disabilities. These limitations could effectively bar recourse under State laws in such cases. For these reasons it was believed that provision should be made for the compensation of disabilities or death due to specific hazards peculiar to work with radiation and to such toxic materials as beryllium, when they were not adequately covered by workmen's compensation or occupational disease statutes.

Therefore, it was determined that, if after careful review and consideration of the nature of the contractor's work, the applicable workmen's compensation law, the contractor's insurance arrangements and his existing employee welfare plans, supplementary coverage were found necessary, it should be provided, if possible, by voluntary workmen's compensation insurance. This kind of insurance provides that the insurance company will offer an injured employee, whose injury does not fall within the scope of the workmen's compensation law, the same benefits to which he would be entitled had his injury been compensable under the law.[15]

As pointed out in section 3 of this part, some States limit compensation payments for medical care. There are certain types of injuries and occupational diseases which might result from hazards not commonly found outside the atomic energy industry which might require unusually expensive or prolonged medical diagnosis and treatment. There are also injuries in which rather special medical attention might be required at an expense not contemplated by the workmen's compensation statute. This limitation in State laws has been overcome by authorizing contractors to obtain a standard endorsement which provides medical treatment in excess of the statutory benefits up to as much as $100,000 for each case of disability.[16]

---

[15] Voluntary workmen's compensation endorsements are presently included in the insurance policies of the following contractors:
Contractor and location of operations:
Argonne National Laboratory: Illinois and Idaho
University of California: New Mexico
Union Carbide: Tennessee and Kentucky
Phillips Petroleum Co.: Idaho
University of Tennessee: Tennessee
Pratt & Whitney: Connecticut, Idaho, and Tennessee
Sandia Corp. is a self-insurer in New Mexico and Westinghouse a self-insurer in Pennsylvania. Both of these contractors provide for voluntary compensation in their self-insurance programs.

[16] Extra statutory medical coverage is included in the insurance policies of the following contractors:
Contractor and location of operations:
American Car & Foundry: New Mexico
Bendix Aviation: Missouri
Union Carbide: Kentucky and Tennessee
E. I. du Pont: South Carolina
H. K. Ferguson: Tennessee
National Lead, Inc.: Massachusetts
Oak Ridge Institute of Nuclear Studies: Tennessee
Pratt & Whitney: Connecticut and Tennessee
University of Tennessee: Tennessee
Zia Co.: New Mexico
Sandia Corp., a self-insurer in New Mexico, and Westinghouse, a self-insurer in Pennsylvania, provide for extra statutory medical coverage in their self-insurance plans.

Finally, as a result of the 1952 reappraisal, it was determined that if any unusual situations were discovered which could not be taken care of by the remedies described above, a special benefit plan could be authorized to close the gaps. It was concluded that the role of the special benefit plan should be limited to unusual situations. As pointed out earlier, it was not recommended that existing benefit plans be modified or abandoned.

Since the adoption of this new concept of the special benefit plan, it has been used twice: in the contract with Iowa State College of Agriculture and Mechanical Arts, and in the contract with Westinghouse covering its operations in Pennsylvania and Idaho.

Section 5. Radiation Accidents, Injuries, and Overexposures—AEC Contractors

INTRODUCTION

This section discusses three categories of radiation accidents that have occurred in either MED or AEC contract operations: first, those that have resulted in lost-time injuries; second, those which, although not resulting in lost-time injuries, have nevertheless caused individuals to receive more than the maximum permissible levels of whole body radiation exposure; and finally radiation accidents which have *not* resulted in employees being injured or overexposed.

LOST TIME INJURIES

At the outset it is important to bear in mind that the lost-time injuries identified in table 5 are not necessarily clinically diagnosed "radiation injuries." Rather this table presents a complete list of all reported instances which are appropriately classified as "lost-time injuries" or "disabling injuries" in accordance with the prevailing definitions of the American Standards Association, the organization which has developed the standard method used by American industry for reporting and measuring work-injury experience. Among the categories of injuries included in the ASA definitions, in addition to the more obvious ones—such as death, permanent total disability, and permanent partial disability—are work-connected disabilities which prevent an individual from performing his regularly established job during the time interval corresponding to the hours of his regular shift on any one or more days. Under ASA standards, an injury of this type is classified as "temporary total disability."

Thus, included in table 5 are a number of lost-time injuries which in terms of medical opinion would not in fact be classified as injuries in the normal clinical sense of the term. In other words, they would not be classified as "radiation injuries" in the sense that they had been so diagnosed by a physician competent in radiation medicine.[17]

By and large, the columnar headings of table 5 are self-explanatory. However, a brief note on the columns grouped under "Method of Compensation" is necessary for a complete understanding of the information reported in the eight subcolumns. The first five subcolumns refer to five of the six major classifications of injuries under which benefits are paid in accordance with workmen's compensation

[17] See section 3, part II, for a statement of what under AEC requirements is considered reportable as a radiation injury.

if
are
be
he
ed
be

an,
of
ng-

—

at
se
gh
id-
ole
ve

in-
sed
of
me
ing
ion
try
the
to
ty,
ies
ed
lar
of

ich
ies
uld
ad
17
ry.
of
the
ub-
der
ion

as a

TABLE 5

REPORTED RADIATION ACCIDENTS RESULTING IN LOST TIME INJURIES

(As defined in American Standards Association Methods for reporting work injuries - ASA Z16-1-1954)

Date	Location	Number Involved	Source of Injury	Nature of Injury	Exposure	Days Lost	Method of Compensation							
							Workmen's Compensation					Other		
							Death Benefits	Funeral Expense	Temp. Total	Perm. Partial	Med. Hosp.	AEC Sp. Ben.	Occup. Disab.	Med. Hosp.
					80KV X-Ray / GAMMA RAY									
8/21/45	Los Alamos	Two	Chain reaction in experimental critical assembly	(1) Fatality	(1) 480 r / 110 r	6000		X				X		
				(2) No clinically diagnosed injury	(2) 31 r / 1 r	60							X	X
					80KV X-Ray / GAMMA Ray									
5/21/46	Los Alamos	Eight	Chain reaction in experimental critical assembly	(1) Fatality	(1) 1930 r / 114 r	6000		X			X	X		
				(2) Skin rash, loss of hair and other symptoms	(2) 390 r / 26 r	70				X	X	X	X	X
				(3) Skin rash and other symptoms	(3) NA / NA	1/				X	X	X	1/	
				(4) No clinically diagnosed injury	(4) 186 r / 10.7 r	14							X	X
				(5) No clinically diagnosed injury	(5) 140 r / 8.7 r	18							X	X
				(6) No clinically diagnosed injury	(6) 55 r / 4.4 r	4							X	X
				(7) No clinically diagnosed injury	(7) 42 r / 3 r	4							X	X
				(8) No clinically diagnosed injury	(8) 33 r / 2.41 r	4							X	X
5/14/48	Eniwetok Proving Ground	Four	Improper handling of fission sample	Beta ray burns to hand	1.7 r 2/	36			X		X		X	
					4.5 r 2/	36			X		X		X	
					5.5 r 2/	36			X		X		X	
					17 r 2/	36			X		X		X	

5/14/48	Eniwetok Proving Ground	Four	Improper handling of fission sample	Beta ray burns to hand	1.7 r 2/ 4.5 r 2/ 5.5 r 2/ 17 r 2/	36 36 36 36			X X X X		X X X X		X X X X		
9/7/48	Los Alamos	One	Unpacking radioactive material	Beta ray burns to ankle	NA 3/	36			X		X		X		
6/2/52	Chicago	Four	Manual withdrawal of control rod from reactor	No clinically diagnosed injury	190 rem 160 rem 70 rem 12 rem	23 23 34 23			X X X X	 X 	X X X X		X X X X		
7/9/52	Los Alamos	One	Handling radioactive material with torn glove	Beta ray burns to hands	NA 4/	3			X		X		X		
3/1/55	Nevada Test Site	One	Entering exclusion area during test	No clinically diagnosed injury	39 r	19					X				
7/27/55	National Reactor Testing Station	One	Radioactive particle entering ear canal	Partial loss of hearing	Not detectable	12							X	X	
4/30/56	Los Alamos	One	Handling radioactive material with torn glove	Beta burns to hand	NA 5/	14			X	X	X		X		
6/18/56	Hanford	One	Escape of plutonium solution into control room	Contamination of exposed skin surfaces. No clinically diagnosed injury	In excess of 40,000 d/m alpha	4							X	X	
2/18/57	Berkeley	One	6/	Fatality due to leukemia	6/	6000	X								
6/14/57	Rocky Flats	One	Explosion in "dry box"	Plutonium lodged in finger, necessitating amputation	3.2 m/c Pu	50				X	X		X		

				(7) No clinically diagnosed injury	(7) 42 r	3 r	4							X	X	
				(8) No clinically diagnosed injury	(8) 33 r	2.41 r	4							X	X	
5/14/48	Eniwetok Proving Ground	Four	Improper handling of fission sample	Beta ray burns to hand	1.7 r 2/		36			X		X		X		
					4.5 r 2/		36			X		X		X		
					5.5 r 2/		36			X		X		X		
					17 r 2/		36			X		X		X		
9/7/48	Los Alamos	One	Unpacking radioactive material	Beta ray burns to ankle	NA 3/		36			X		X		X		
6/2/52	Chicago	Four	Manual withdrawal of control rod from reactor	No clinically diagnosed injury	190 rem		23			X		X		X		
					160 rem		23			X		X		X		
					70 rem		34			X	X	X		X		
					12 rem		23			X		X		X		
7/9/52	Los Alamos	One	Handling radioactive material with torn glove	Beta ray burns to hands	NA 4/		3			X		X		X		
3/1/55	Nevada Test Site	One	Entering exclusion area during test	No clinically diagnosed injury	39 r		19					X				
7/27/55	National Reactor Testing Station	One	Radioactive particle entering ear canal	Partial loss of hearing	Not detectable		12							X	X	
4/30/56	Los Alamos	One	Handling radioactive material with torn glove	Beta burns to hand	NA 5/		14			X	X	X		X		
6/18/56	Hanford	One	Escape of plutonium solution into control room	Contamination of exposed skin surfaces. No clinically diagnosed injury	In excess of 40,000 d/m alpha		4							X	X	
2/18/57	Berkeley	One	6/	Fatality due to leukemia	6/		6000	X								
6/14/57	Rocky Flats	One	Explosion in "dry box"	Plutonium lodged in finger, necessitating amputation	3.2 m/c Pu		50				X	X		X		
10/4/57	Oak Ridge (ORNL)	One	Entered room in which radioactive material present	No clinically diagnosed injury	63 r		5							X	X	
6/16/58	Oak Ridge (Y-12 Plant)	Eight	Criticality incident caused by draining enriched uranium in drum of water	7/	461 rem		83			X				X	X	
					341 rem		83			X				X	X	
					428 rem		83			X				X	X	
					413 rem		83			X				X	X	
					298 rem		83			X				X	X	
					86 rem		34			X				X	X	
					86 rem		65			X				X	X	
					29 rem		41			X						

1/ Employee had received termination notice prior to accident.

2/ Exposure refers to whole body gamma radiation. Injury caused by beta ray dose, amount of which exposure not available.

3/ Amount of beta ray dose not available. Total gamma ray exposure during week in which accident occured was 0.27 rem.

4/ Amount of beta ray dose not available. Total gamma ray exposure during week in which accident occured was 1.8 rem.

5/ Amount of beta ray dose not available. Total gamma ray exposure during week in which accident occured was 2.0 rem.

6/ Employee's physician reported to State Compensation Insurance Fund that his "patient's leukemia was probably caused by acute and chronic exposure to ionizing radiations during the course of his work at the University of California". On the basis of this report, the employee's widow was awarded a dependency benefit under the provisions of the California Workmen's Compensation Act. The University did not press or support the claim and, in fact, was neither asked for any statement of its position nor given an opportunity to testify. Nineteen months prior to employee's death, University filed with the state an industrial injury report on employee reporting as an industrial accident the fact that he had received "exposure to radioactive material" while "performing chemical purifications".

7/ Three employees not requiring prolonged hospital care exhibited mild changes in blood elements but showed no symptoms of injury. The five employees requiring longer hospitalization showed significant decreases in blood elements and other clinical and laboratory findings characteristic of more severe radiation damage such as mild nausea and vomiting, and indications of possible hemorrhagic complications, although no bleeding actually occured.

34434 0-59 (Face p. 93)

statutes. The sixth category "Permanent Total Disability" has been omitted from the table because none of the reported lost-time injuries fall in this category. The classification "Death Benefits" and "Funeral Expenses" are self-explanatory. The third category "Temporary Total Disability" represents that classification of compensation case which ends with the apparent recovery of the injured person and his return to work. Compensation benefits under this category are normally paid to reimburse employees for a percentage of their lost wages during the period of temporary disability. A "Permanent Partial Disability" is classified in workmen's compensation laws as a specific or "schedule" injury, such as loss of, or loss of use of, a member; or a "nonschedule" injury which is an injury of a more general nature, such as, for example, disability caused by injury to the head or back. The final workmen's compensation category refers to the medical benefits received by an injured employee to meet, at least in part, the cost of medical care and treatment during his disability. All of these categories of benefits are discussed in greater detail in section 3 of this part.

The three columns under the heading "Other" refer to the benefits received by injured employees (or in the case of fatalities, their beneficiaries) which were paid by the contractors in supplementation of or in lieu of any benefits paid under applicable workmen's compensation statutes. The first of the categories—AEC Special Benefit Plan—is discussed in section 4. The column headed "Occupational Disability" is meant to describe the generally common practice in industry today of making employees whole for any wage loss suffered during periods of disability. The final category, "Medical-Hospital," refers to benefits of this nature which employees receive from their employers in addition to benefits received under applicable State compensation laws.

It is believed that table 5 includes all instances in which compensation was received by employees for lost-time injuries which in the opinion of the Commission or its contractors, or in the judgment of compensation boards, resulted from radiation accidents. However, in addition to the cases reported in the table, there are two cases presently pending before State compensation bodies where the claimants allege that injury was occasioned by radiation exposure. The first of these involves an allegation that an employee's death was due to radiation exposure. The claim was originally denied, but it is believed that further litigation is contemplated. The second case involves one of the four individuals reported in table 5—the June 2, 1952, Chicago incident. The claim here is that the employee had suffered a permanent partial disability as a result of the accident. This matter is still pending.

OVEREXPOSURES

Table 6 identifies the salient facts concerning all reported radiation accidents (except as qualified in the table) which have caused employees to receive *whole body* radiation exposures or *internal depositions* greater than permissible levels but have *not* resulted in lost-time injuries. No effort has been made to present a similar list for reported overexposures to *parts of the body*.

RADIATION ACCIDENTS

Table 7 does not purport to represent a complete list of all radiation accidents that have occurred in which individuals present at the time of the accident were neither injured nor overexposed. Rather it represents a list of illustrative examples of such accidents, and is included in this section to demonstrate that radiation accidents may occur in which persons in the immediate environs at the time of the accident do not receive injuries or exposures in excess of permissible levels.

TABLE 6.—*Reported radiation accidents not resulting in lost-time injuries but involving personnel exposures beyond permissible whole body limits*

Date	Location	Number involved	Nature of accident	Exposure	Comments
June 4, 1945	Los Alamos	2	Supercritical assembly of fissionable material.	(1) 66.5 rep; (2) 66.5 rep	A total of 3 individuals involved in accident. The other individual reported in table 7.
1947–48	St. Louis	16	(1)	(1)	These are included not because of any accident but because each of their accumulated annual exposure exceeded 15 rem. Highest exposure of 16 was 23.5 rem, whereas controlling MPD in 1947 was 25 rem.
Feb. 16, 1955	Hanford	1	Doing semiroutine maintenance work on plutonium-contaminated equipment.	1½ times amount permitted for internal deposition.	
Dec. 10, 1956 Jan. 2, 1957	Pittsburgh (Carnegie Institute of Technology).	1	Handling irradiated lithium fluoride and potassium chloride.	30 r	Exposure represents cumulative amount received on 2 occasions occurring on dates indicated. Cyclotron involved built partly at AEC expense and title rests with AEC.
Jan. 18, 1956	Nevada test site	2	Recovering samples from a test area	(1) 19 r; (2) 28 r	A total of 4 individuals involved in accident. The other 2 are reported in table 7.
July 23, 1956	National Reactor Testing Station.	1	Exposed during scheduled refueling in experimental installation operation.	21 r	A total of 8 individuals involved in accident. The other 7 are reported in table 7.

[1] See comments.

TABLE 7.—*Illustrative examples of radiation accidents not involving personnel exposures beyond permissible limits*

Date	Location	Number involved	Nature of accident	Exposure
June 4, 1945	Los Alamos	[1] 1	Supercritical assembly of fissionable material	7.4 rep.
December 1949	do	1	Supercriticality in reactor caused by manual testing of mechanisms for control rods.	2.5 r.
May 7, 1954	Hanford	4	Explosion in pot of plutonium turnings	Slight plutonium body burden.
Jan. 10, 1955	National Reactor Testing Station	[2]	Operational incident caused air contamination in chemical plant building.	324 d/m per 5 milliliters.
June 11, 1955	Schenectady	70	Fire involving radioactive sodium	From 0 to 1.7 r.
Jan. 17, 1956	Hanford	1	Rubber gloves deteriorated by plutonium bearing organic solution	100 milligrams plutonium to hands.
Jan. 18, 1956	Nevada test site	[1] 2	Recovering samples from a test area	(1) 14 r; (2) 4 r.
Feb. 1, 1956	Oak Ridge (ORNL)	4	Unanticipated criticality during experiment	0 to 1.5 rem.
June 16, 1956	Aiken	1	Inhalation of radioactive gas	7 rad.
June 21, 1956	Los Alamos	8	Blotting paper contaminated with radioactive material blew around room.	Not available.
July 23, 1956	National Reactor Testing Station	[1] 7	Exposed during a scheduled refueling in experimental installation operations.	(1) 6.2 r; (2) 3.9 r; (3) 6.1 r; (4) 10.6 r; (5) 2.9 r; (6) 2.6 r; (7) 2.5 r.
Apr. 22, 1957	Hanford	1	Torn glove resulted in employee's thumb and finger being contaminated.	15 m/c plutonium.
Sept. 21, 1956	do	1	Plutonium-bearing solution splashed upon employee	Slight plutonium body burden.
Aug. 16, 1957	Los Alamos	2	Explosion in plutonium processing hood	Less than 1 percent maximum permissible body burden of plutonium.

[1] Other individuals involved in accident reported in table 6.

[2] Exact number not known.

Section 6.—Summary of Reported Overexposures—AEC Licensees

INTRODUCTION

10 CFR 20 "Standards for Protection Against Radiation" prescribes the permissible levels of radiation exposure for licensee personnel and others who use and/or are exposed to the radiations emitted by by-product material controlled by the Atomic Energy Act of 1954. These levels are based on an exposure period of 1 week and under certain circumstances a 13-week period. The regulation further provides that should a person receive a radiation exposure in excess of the amount prescribed, the person shall limit his future exposure until his accumulated total is again below the prescribed weekly average. The regulation further sets forth the requirements for reporting radiation incidents.

In general, the device most widely used by a licensee to determine radiation exposure is the film badge; a self-contained packet containing sensitive films which, when developed, show the amount of radiation to which the film has been exposed.

Each overexposure incident is reviewed and in those cases where the weekly exposure is believed to be in excess of 3 rem an investigation is conducted to determine the facts and circumstances attendant thereto. Special investigations of overexposures of less than 3 rem for a week normally are not conducted unless there are unusual circumstances that warrant immediate examination. Exposures of this nature are usually reviewed during a subsequent routine inspection.

REPORTED INCIDENTS

By the fall of 1958, a total of about 60 persons had received exposures in excess of prescribed limits but less than 3 rem in a week. In each case, subsequent exposures were limited until the prescribed average accumulated level or less was attained.

Through this same period 28 persons employed by licensees received estimated exposures in excess of 3 rem per week. The pertinent details of the 16 incidents resulting in these overexposures are summarized in table 8. In addition to the listed cases, there are several others for which investigations are not yet complete.

TABLE 8.—*Summary of AEC licensee radiation incidents involving exposures of persons in excess of 3 rem*

Date	Location	Number of persons involved	Nature of incident	Approximate [1] exposure	Comments
1957					
March	Texas	2	During operation of opening a container of radioactive material, dust escaped to the working area which resulted in body contamination of 2 employees.	(1) not determined (2) not determined	A finger of 1 employee showed radiation burns; a localized area on the body of the other employee received radiation burns as a result of skin contamination.
June	Connecticut	1	Employee exposed during radiographic operation.	5 rem (film badge)	
October	New York	1	Employee calibrating gage containing radioactive material.	130 rem (film badge)	Overexposure, beta. Whole body exposure substantially less than 130 rem due to orientation and nature of the source.
Do	Massachusetts	1	Exposure received during radiographic operation using open-air technique.	5 rem (film badge)	
December	Connecticut	1	Operator unknowingly worked in the vicinity of a source when it was out of the storage container.	9 rem (film badge)	
1958					
January	Illinois	1	Employee accidently placed thumb on source	47 rem (calculated)	Exposure to thumb, beta. Film badge showed less than 0.05 rem whole body exposure.
Do	North Carolina	1	During experimental maintenance operations employee handled radioactive source.	725 rem (calculated)	Overexposure, beta. Exposure extrapolated from film badge worn on employee's right arm and the overexposure limited to employee's hand and forearm.
February	Ohio	2	During radiography operation using open air technique employee briefly handled the source.	55 rem (calculated) 88 rem (calculated).	Excessive exposure to fingers only. Film badge showed whole body exposures of 0.38 rem and 0.045 rem.
March	California	1	Nonemployee unknowingly entered radiation area during radiography operations.	8 rem (calculated)	
Do	Massachusetts	2	Equipment failure during administration of radioactive material to patient caused physicians to be exposed.	5 rem (calculated) 5 rem (calculated).	Overexposure limited to the thumb and arm of 1 physician and the finger of the other. Whole body exposures of both physicians within prescribed limits.
April	New York	1	Exposure occurred as a result of a spill contaminating rubber gloves and small area of table top.	6 rem (calculated)	

May	California	10	During radiographic operations source became detached from equipment and remained in construction area for about 4 days during which time 10 persons were known to have received exposures. 2 persons held source in hands.	(1) 81 rem whole body and 3,900 rem to the hand. (2) 26 rem whole body. (3) 26 rem whole body. (4) 34 rem whole body and 400 rem to the hand. (5) 5 rem whole body. (6) 5 rem whole body. (7) 5 rem whole body. (8) 5 rem whole body. (9) 7 rem whole body. (10) 30 rem whole body (film badge) (except as noted, all above exposures calculated).	
June	Utah	1	Employee failed to follow established procedure during a mechanical failure of equipment. Employee handled source briefly.	1,200 rem (calculated)	Major portion of exposure limited to tips of fingers and hand. Whole body exposure calculated as 3 rem. Hand showed slight erythema.
September	New York	1	Lead bricks inadvertently moved from around sealed source exposing employee.	10 rem (film badge)	
Do	do	1	Employee exposed while performing routine room surveys.	162 rem (film badge)	Exposure limited to the hands. Film badg showed whole body exposure of 0.125 rem.
October	Massachusetts	1	During experimental operations employee exposed to unshielded source.	1,000 rem (calculated)	Stated exposure limited to hands. Whole body exposure 1.435 rem according to film badge.

[1] Film badge data received by the Commission from the licensee.

APPENDIXES

Appendix A–1

Recommendations of NCRP 1951–58

NBS handbook No.	Title	Date
15	X-ray protection. Superseded by H20.	May 16, 1931.
18	Radium protection for amounts up to 300 milligrams. Superseded by H23.	Mar. 17, 1934.
20	X-ray protection. Superseded by H41.	July 24, 1936.
23	Radium protection. Superseded by H54.	Aug. 25, 1938.
41	Medical X-ray protection up to 2,000,000 volts. Superseded by H60.	Mar. 30, 1949.
42	Safe handling of radioactive isotopes.	September 1949.
48	Control and removal of radioactive contamination in laboratories.	Dec. 15, 1951.
49	Recommendations for waste disposal of phosphorus 32 and iodine 131 for medical users.	Nov. 2, 1951.
51	Radiological monitoring methods and instruments.	Apr. 7, 1952.
52	Maximum permissible amounts of radioisotopes in the human body and maximum permissible concentrations in air and water.	Mar. 20, 1953.
53	Recommendations for the disposal of carbon 14 wastes.	Oct. 26, 1953.
54	Protection against radiations from radium, cobalt 60, and cesium 137.	Sept. 1, 1954.
55	Protection against betatron-synchrotron radiations up to 100,000,000 electron volts.	Feb. 26, 1954.
56	Safe handling of cadavers containing radioactive isotopes.	Oct. 26, 1953.
58	Radioactive-waste disposal in the ocean.	Aug. 25, 1954.
59	Permissible dose from external sources of ionizing radiation.	Sept. 24, 1954.
60	X-ray protection.	Dec. 1, 1955.
61	Regulation of radiation exposure by legislative means.	Dec. 9, 1955.
63	Protection against neutron radiation up to 30,000,000 electron volts.	Nov. 22, 1957.
65	Safe handling of bodies containing radioactive isotopes (a guide for surgeons, pathologists and general directors).	July 10, 1958.

Appendix A–2

MEMBERSHIP LIST, NATIONAL COMMITTEE ON RADIATION PROTECTION AND MEASUREMENTS (NCRP)

Revised November 1, 1958

Chairman: Lauriston S. Taylor
Secretary: Sarah W. Raskin

Executive Committee

Members:
- L. S. Taylor, Chairman
- E. C. Barnes
- C. B. Braestrup
- C. L. Dunham
- H. B. Glass
- H. M. Parker
- C. Powell

Members—Continued
- R. S. Stone
- Shields Warren

Consultants:
- J. C. Bugher
- G. Failla
- E. G. Williams

Main Committee (and Organization Represented)

H. L. Andrews, USPHS and Subcommittee Chairman.
E. C. Barnes, American Industrial Hygiene Association.
A. C. Blackman, International Association of Government Labor Officials.

C. B. Braestrup, Radiological Society of North America and Subcommittee Chairman.
J. C. Bugher, representative at large.
R. H. Chamberlain, American College of Radiology.
W. D. Claus, USAEC.
C. L. Dunham, USAEC.
T. P. Eberhard, American Radium Society and Subcommittee Chairman.
T. C. Evans, American Roentgen Ray Society.
G. Failla, representative at large.
J. W. Healy, Health Physics Society and Subcommittee Chairman.
P. C. Hodges, American Medical Association.
M. Kleinfeld, International Association of Government Labor Officials.
H. W. Koch, Subcommittee Chairman.
W. Langham, Subcommittee Chairman.
R. M. Lechausse, Colonel, U.S. Air Force.
G. V. Leroy, Subcommittee Chairman.
W. B. Mann, Subcommittee Chairman.
W. A. McAdams, Atomic Industrial Forum and Subcommittee Chairman.
G. M. McDonnel, Lieutenant Colonel, U.S. Army.
G. W. Morgan, Subcommittee Chairman.
K. Z. Morgan, Health Physics Society and Subcommittee Chairman.
R. J. Nelsen, American Dental Association.
R. R. Newell, American Roentgen Ray Society.
C. Powell, USPHS.
E. H. Quimby, American Radium Society and Subcommittee Chairman.
S. W. Raskin, NBS.
J. A. Reynolds, National Electrical Manufacturers Association.
H. H. Rossi, Subcommittee Chairman.
M. D. Schulz, American College of Radiology.
L. S. Skaggs, Subcommittee Chairman.
J. H. Sterner, American Industrial Hygiene Association.
R. S. Stone, Radiological Society of North America.
L. S. Taylor, NBS.
E. D. Trout, National Electrical Manufacturing Association.
Shields Warren, representative at large.
J. L. Weatherwax.
E. G. Williams, USPHS.
S. F. Williams, Captain, MC USN.
H. O. Wyckoff, NBS.

Subcommittee 1. Permissible Dose From External Sources

A. H. Dowdy	H. J. Muller	C. Stern
G. Failla	H. M. Parker	R. S. Stone
H. Friedell		

Note.—The work of this subcommittee is temporarily the responsibility of the Executive Committee together with the subcommittee members.

Subcommittee 2. Permissible Internal Dose

K. Z. Morgan, Chairman	J. W. Healy	J. E. Rose
A. M. Brues	J. B. Hursh	W. S. Snyder
P. Durbin	L. D. Marinelli	Shields Warren
G. Failla		

Subcommittee 3. X-Rays up to 2 Million Volts

T. P. Eberhard, Chairman	E. Miller	R. R. Newell
C. B. Braestrup	J. M. Mozley	S. W. Smith
E. Focht	R. J. Nelsen	E. D. Trout
J. Hale		

Subcommittee 4. Heavy Particles (Neutrons, Protons, and Heavier)

H. H. Rossi, Chairman	D. B. Cowie	W. S. Snyder
E. P. Flizard	T. C. Evans	C. A. Tobias
R. S. Caswell	D. J. Hughes	
F. P. Cowan	L. D. Marinelli	

SUBCOMMITTEE 5. ELECTRONS, GAMMA RAYS AND X-RAYS ABOVE 2 MILLION VOLTS

H. W. Koch, Chairman	D. B. Cowie	L. D. Marinelli
G. C. Baldwin	U. Fano	D. Scag
C. B. Braestrup	J. S. Laughlin	L. S. Skaggs

SUBCOMMITTEE 6. HANDLING OF RADIOACTIVE ISOTOPES AND FISSION PRODUCTS

J. W. Healy, Chairman	D. Hull	W. K. Sinclair
P. C. Aebersold	L. D. Marinelli	M. M. D. Williams
G. Failla	H. M. Parker	
S. Feitelberg	J. E. Rose	

SUBCOMMITTEE 7. MONITORING METHODS AND INSTRUMENTS

H. L. Andrews, Chairman	R. Lapp	E. G. Williams
C. B. Braestrup	W. H. Ray	
J. W. Healy	J. E. Rose	

SUBCOMMITTEE 8. WASTE DISPOSAL AND DECONTAMINATION

NOTE.—This subcommittee has been inactivated.

SUBCOMMITTEE 9. PROTECTION AGAINST RADIATIONS FROM RA, CO^{60}, AND CS^{137} ENCAPSULATED SOURCES

C. B. Braestrup, Chairman	T. P. Eberhard	E. L. Saenger
H. Blatz	G. Ferlazzo	W. K. Sinclair
M. Brucer	J. R. Mason	H. O. Wyckoff
	E. H. Quimby	

SUBCOMMITTEE 10. REGULATION OF RADIATION EXPOSURE DOSE

Working group

W. A. McAdams, Chairman	J. Lieben	L. Rogers
P. Hodges	E. P. Pendergrass	L. S. Taylor
	J. A. Reynolds	J. C. Terrill, Jr.

Advisory group

W. H. Ealls	M. Kleinfeld	F. A. Norton
G. C. Frampton	L. Manning	M. Stein
L. M. Hydeman	R. R. Newell	E. Dale Trout

SUBCOMMITTEE 11. INCINERATION OF RADIOACTIVE WASTE

G. W. Morgan, Chairman	S. Feitelberg	J. A. Lieberman
R. C. Corey	W. H. Langham	L. Silverman

SUBCOMMITTEE 12. ELECTRON PROTECTION

L. S. Skaggs, Chairman	H. W. Koch	R. F. Post
E. A. Burrill	J. S. Laughlin	E. D. Trout

SUBCOMMITTEE 13. SAFE HANDLING OF BODIES CONTAINING RADIOACTIVE ISOTOPES

E. H. Quimby, Chairman	L. R. Peet	R. Yalow
S. Feitelberg	W. B. Stewart	E. G. Maier, consultant

34434—59——8

SUBCOMMITTEE 14. PERMISSIBLE EXPOSURE DOSES UNDER EMERGENCY CONDITIONS

Members

G. V. Leroy, Chairman
H. L. Andrews
H. Blair
G. Casarett
G. Dunning
E. Green
P. Henshaw
R. Hasterlik
L. S. Taylor
E. G. Williams

Consultants

C. B. Braestrup
R. F. Brown
J. Bugher
A. H. Dowdy
L. H. Garland
L. H. Hempelmann
R. D. Huntoon
H. M. Parker
G. A. Sacher
R. S. Stone
Shields Warren

SUBCOMMITTEE M–1. STANDARDS AND MEASUREMENT OF RADIOACTIVITY FOR RADIOLOGICAL USE

Members

W. B. Mann, Chairman
T. P. Eberhard
K. W. Geiger
W. Gross
R. Rugh
W. K. Sinclair

Consultants

P. J. Campion
C. L. Comar
S. D. Garfinkle
E. H. Quimby
S. A. Reynolds
H. H. Seliger

TASK GROUPS

(1) Preparation of Standards and Procedures for Their Measurement

K. W. Geiger, Chairman
P. J. Campion
S. B. Garfinkle
J. A. Reynolds

(2) Preparation and Measurement of Radionuclides for Clinical and Biological Application

W. K. Sinclair, Chairman
C. B. Comar
T. P. Eberhard
S. Feitelberg
W. Gross
John Hale
E. H. Quimby

SUBCOMMITTEE M–2. STANDARDS AND MEASUREMENT OF RADIOLOGICAL EXPOSURE DOSE

Members

H. O. Wyckoff, Chairman
C. B. Braestrup
R. S. Caswell
C. Garrett
J. Hale
J. S. Laughlin
R. R. Newell

Consultants

W. A. Jennings
A. McCrea
R. T. Mooney
J. S. Pruitt
G. R. Ringo
R. H. Ritchie
R. Robbins
K. C. Tsien
E. Tochilin

TASK GROUPS

(1) Instruments for Measurement in Roentgens

H. O. Wyckoff, Chairman
C. Garrett

(2) Measurement of Radiation Output of Protons and Electrons

J. S. Pruitt, Chairman.

(3) Measurement of Neutron Flux and Spectra

R. S. Caswell, Chairman
G. R. Ringo
R. H. Ritchie
E. Tochilin

(4) Clinical Measurement of Exposure Dose and Depth Dose

C. B. Braestrup, Chairman
C. Garrett
J. Hale
W. A. Jennings
A. McCrea
R. T. Mooney
R. Robbins
K. C. Tsien

SUBCOMMITTEE M–3. STANDARDS AND MEASUREMENT OF ABSORBED RADIATION DOSE

Members

H. O. Wyckoff, Chairman
G. S. Hurst
H. W. Koch
H. M. Parker
W. C. Roesch
H. H. Rossi
G. N. Whyte

Consultants

F. H. Attix
N. Berger
R. S. Caswell
D. V. Cormack
W. Gross
H. E. Johns
F. C. Maienschein
J. W. Motz
J. A. Sayeg
R. H. Schuler
R. W. Wallace

TASK GROUPS

(1) Measurement of Absorbed Dose of Neutrons, and of Mixed Neutrons and γ-Rays

G. S. Hurst, Chairman
R. S. Caswell
F. C. Maienschein
H. H. Rossi
J. A. Sayeg
R. H. Schuler
R. W. Wallace

(2) Measurement of and Data on Spectra of X-rays and Electrons

H. W. Koch, Chairman
D. V. Cormack
H. E. Johns
J. S. Laughlin
J. W. Motz

(3) Measurement of Stopping Power Ratios and Analysis of Present Data

W. C. Roesch, Chairman
F. H. Attix
M. Berger
W. Gross
G. N. Whyte

SUBCOMMITTEE M–4. RELATIVE BIOLOGICAL EFFECTIVENESS

Members

W. H. Langham, Chairman
V. P. Bond
R. D. Evans
T. C. Evans
M. P. Finkel
J. N. Stannard
J. B. Storer
C. A. Tobias
A. C. Upton

Consultants

H. A. Blair
A. M. Brues
H. I. Kohn
R. E. Zirkle

Dr. Paul Aebersold, Office of Industrial Development (USAEC), Washington, D.C.
Dr. H. L. Andrews, U.S. Public Health Service, National Institutes of Health, Bethesda, Md.
*Mr. Frank H. Attix, Washington, D.C.
Dr. G. C. Baldwin, General Engineering Laboratory, General Electric Co., Schenectady, N.Y.
Mr. E. C. Barnes, Westinghouse Electric Corp., Pittsburgh, Pa.
*Dr. Martin Berger, Radiation Theory Section, National Bureau of Standards, Washington, D.C.

Mr. Alfred C. Blackman, Division of Industrial Safety, California Department of Industrial Relations, San Francisco, Calif.
Dr. Harry Blair, Director AEC Projects, University of Rochester, Rochester, N.Y.
Dr. Hanson Blatz, New York Operations Office (USAEC).
Dr. E. P. Blizard, Oak Ridge National Laboratory, Oak Ridge, Tenn.
Dr. Victor P. Bond, Brookhaven National Laboratory, Upton, Long Island, N.Y.
Dr. C. B. Braestrup, Physics Laboratory, Francis Delafield Hospital, New York, N.Y.
*Dr. Reynold F. Brown, Physical Division, Radiation Safety, University of California School of Medicine, San Francisco, Calif.
Dr. Marshall Brucer, Medical Division, Oak Ridge Institute Nuclear Studies, Oak Ridge, Tenn.
Dr. A. M. Brues, Director Biology Division, Argonne National Laboratory, Lemont, Ill.
Dr. John C. Bugher, Medical Education and Public Health, Rockefeller Foundation, New York, N.Y.
Mr. E. A. Burrill, High Voltage Engineering Corp., Cambridge, Mass.
*Mr. P. J. Campion, Atomic Energy of Canada, Ltd., Ontario, Canada.
Dr. George Casarett, University of Rochester, Rochester, N.Y.
Dr. Randall S. Caswell, Neutron Physics Section, National Bureau of Standards, Washington, D.C.
Dr. Richard H. Chamberlain, University of Pennsylvania Hospital, Philadelphia, Pa.
Dr. Walter D. Claus, Division of Biology and Medicine (USAEC), Washington, D.C.
*Dr. C. L. Comar, New York State Veterinary College, Cornell University, Ithaca, N.Y.
Mr. R. C. Corey, Division of Solid Fuels Technology, Bureau of Mines Region V (Interior), Pittsburgh, Pa.
*Dr. D. V. Cormack, Saskatoon Cancer Clinic, University Hospital. Saskatoon, Saskatchewan, Canada.
Dr. F. P. Cowan, Brookhaven National Laboratory, Upton, Long Island, N. Y.
Dr. Dean B. Cowie, Terrestrial Magnetism Department, Carnegie Institution, Washington, D.C.
Dr. Andrew H. Dowdy, UCLA School of Medicine, Los Angeles, Calif.
Dr. Charles L. Dunham, Division of Biology and Medicine (USAEC), Washington, D.C.
Mr. Gordon Dunning, Division of Biology and Medicine (USAEC), Washington, D.C.
Miss Patricia Durbin, Crocker Laboratory, University of California, Berkeley, Calif.
*Mr. William H. Ealls, Coordinator of Atomic Development Activities, State of Ohio, Columbus, Ohio.
Dr. Theodore P. Eberhard, St. Joseph's Mercy Hospital, Ann Arbor, Mich.
Dr. Robley D. Evans, Department of Physics, Massachusetts Institute of Technology, Cambridge, Mass.
Dr. Titus C. Evans, State University of Iowa, Iowa City, Iowa.
Dr. G. Failla, Radiological Department, Columbia University, New York, N.Y.
Dr. Ugo Fano, Radiation Theory Section, National Bureau of Standards, Washington, D.C.
Dr. Sergei Feitelberg, Mount Sinai Hospital, New York, N.Y.
Mr. G. Ferlazzo, College of Medicine, State University of New York, Syracuse, N.Y.
Dr. Miriam P. Finkel, Argonne National Laboratory, Lemont, Ill.
Miss E. Focht, Department of Radiology, New York Hospital, New York, N.Y.
*Prof. George C. Frampton, College of Law, University of Illinois, Urbana, Ill.
Dr. H. Friedell, Western Reserve University, Cleveland, Ohio.
*Mr. Samuel B. Garfinkle, National Bureau of Standards, Radioactivity Section, Washington, D.C.
*Dr. L. H. Garland, 450 Sutter Street, San Francisco, Calif.
Dr. C. Garrett, Radiology Laboratory, National Research Council, Ottawa, Ontario, Canada.
Dr. K. W. Geiger, Radiology Laboratory, National Research Council, Ottawa, Ontario, Canada.

NOTE.—Names marked with an asterisk are consultants.

Dr. H. Bentley Glass, Department of Biology, Johns Hopkins University, Baltimore, Md.
Prof. Earl Green, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine.
Dr. William Gross, Department of Radiology, Columbia University, New York, N.Y.
Dr. John Hale, Department of Radiology, University of Pennsylvania Hospital, Philadelphia, Pa.
Dr. R. Hasterlik, Argonne Cancer Research Hospital, Chicago, Ill.
Dr. J. W. Healy, Health Physics Division, G. E. Nucleonics Project, Richland, Wash.
*Dr. Louis H. Hempermann, Strong Memorial Hospital, Rochester, N.Y.
Dr. Paul Henshaw, Division of Biology and Medicine (USAEC), Washington, D.C.
Dr. Paul Hodges, Department of Radiology, University of Chicago, Chicago, Ill.
Dr. D. J. Hughes, Brookhaven National Laboratory, Upton, Long Island, N.Y.
Dr. D. Hull, California Research Corp., Richmond, Calif.
*Dr. Robert D. Huntoon, National Bureau of Standards, Washington, D.C.
Dr. John B. Hursh, Division of Radiology and Biophysics, University of Rochester, School of Medicine, Rochester, N.Y.
Dr. G. S. Hurst, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.
*Mr. Lee M. Hydeman, Division of Licensing and Regulation (USAEC), Washington, D.C.
Dr. W. A. Jennings, Royal Northern Hospital, London N. 7, England.
*Dr. H. E. Johns, Ontario Cancer Institute, Toronto, Ontario, Canada.
Dr. Morris Kleinfeld, Division of Industrial Hygiene, New York Department of Labor, New York, N.Y.
Dr. H. W. Koch, High Energy Radiation Section, National Bureau of Standards, Washington, D.C.
*Dr. Henry I. Kohn, Medical Center, University of California, San Francisco, Calif.
Dr. W. H. Langham, Biomedical Research, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. Ralph Lapp, Arlington Towers, Arlington, Va.
Dr. John Laughlin, Physics Department, Memorial Hospital, New York, N.Y.
Col. Ralph M. Lechausse, USAF (MC), Office of the Surgeon General, Headquarters U.S. Air Force, Washington, D.C.
Dr. Jan Lieben, Division of Industrial Health, Pennsylvania Department of Health, Harrisburg, Pa.
Dr. George V. Leroy, Billings Hospital, University of Chicago, Chicago, Ill.
Dr. J. A. Lieberman, Division of Reactor Development (USAEC), Washington, D.C.
*Dr. F. C. Maienschein, Oak Ridge National Laboratory, Oak Ridge, Tenn.
*Mr. Emil G. Maier, Funeral Directors, Embalmers and Undertakers Union, New York, N.Y.
Dr. W. B. Mann, Radioactivity Section, National Bureau of Standards, Washington, D.C.
*Mrs. Lucy Manning, U.S. Department of Labor, Washington, D.C.
Dr. L. D. Marinelli, Argonne National Laboratory, Lemont, Ill.
Dr. James R. Mason, Division of Licensing and Regulation (USAEC), Washington, D.C.
Mr. W. A. McAdams, Engineering Standards Service, General Electric Co., Schenectady, N.Y.
*Miss Alice McCrea, Argonne Cancer Research Hospital, Chicago, Ill.
Lt. Col. G. M. McDonnel (MC), Special Assistant to Surgeon General for Nuclear Energy, Office of Surgeon General, Washington, D.C.
Dr. Earl E. Miller, University of California Hospital, San Francisco, Calif.
*Mr. R. T. Mooney, Physics Laboratory, Francis Delafield Hospital, New York, N.Y.
Dr. G. W. Morgan, Division of Licensing and Regulation (USAEC), Washington, D.C.
Dr. Karl Z. Morgan, Health Physics Department, Oak Ridge National Laboratory, Oak Ridge, Tenn.
*Dr. Joseph W. Motz, X-ray Section, National Bureau of Standards, Washington, D.C.
Dr. J. M. Mozley, Johns Hopkins Hospital, Baltimore, Md.
Dr. H. J. Muller, University of Indiana, Bloomington, Ind.
Dr. R. J. Nelsen, Rockville, Md.

Dr. R. R. Newell, Naval Radiological Defense Laboratory, San Francisco, Calif.
*Mr. Frank A. Norton, Chairman, Southern Regional Advisory Council on Nuclear Energy, Dallas, Tex.
Dr. H. M. Parker, General Electric Co., Hanford Works, Richland, Wash.
Mr. Lewis R. Peet, New York, N.Y.
Dr. E. P. Pendergrass, University of Pennsylvania Hospital, Department of Radiology, Philadelphia, Pa.
Dr. R. F. Post, University of California, Radiation Laboratory, Livermore, Calif.
Dr. Clinton Powell, Radiation Studies Section, National Institutes of Health, Bethesda, Md.
*Dr. John Pruitt, High Energy Radiation Section, National Bureau of Standards, Washington, D.C.
Dr. Edith Quimby, Radiological Department, Columbia University, New York, N.Y.
Mrs. Sarah W. Raskin, Radiation Physics Laboratory, National Bureau of Standards, Washington, D.C.
Dr. W. H. Ray, Edgerton Germeshausen & Grier, Inc., Las Vegas, Nev.
Mr. John A. Reynolds, Picker X-ray Corp., Waite Manufacturing Division, Inc., Cleveland, Ohio.
*Dr. G. R. Ringo, Physics Division, Argonne National Laboratory, Lemont, Ill.
*Dr. R. H. Ritchie, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.
*Dr. R. Robbins, Temple University Hospital, Philadelphia, Pa.
Dr. W. C. Roesch, Radiological Sciences Department, General Electric Co., Hanford Atomic Products Operation, Richland, Wash.
Mr. Lester Rogers, Division of Licensing and Regulation (USAEC), Washington, D.C.
Dr. J. E. Rose, Health Physics Division, Argonne National Laboratory, Lemont, Ill.
Dr. H. H. Rossi, Department of Radiology, Columbia University, New York, N.Y.
Prof. Roberts Rugh, Department of Radiology, Columbia University, New York, N.Y.
*Dr. George A. Sacher, Argonne National Laboratory, Lemont, Ill.
Dr. Eugene L. Saenger, Radioisotope Laboratory, Cincinnati General Hospital, Cincinnati, Ohio.
*Dr. J. A. Sayeg, Los Alamos Scientific Laboratory, Los Alamos, N. Mex.
Dr. Dane Scag, Electrical Department, Allis-Chalmers Manufacturing Co., Milwaukee, Wis.
*Dr. R. H. Schuler, Department of Radiation Research, Mellon Institute, Pittsburgh, Pa.
Dr. Milford D. Schulz, Massachusetts General Hospital, Boston, Mass.
*Dr. Howard H. Seliger, Radioactivity Section, National Bureau of Standards, Washington, D.C.
Dr. Leslie Silverman, Department of Industrial Hygiene, Harvard University School of Public Health, Boston, Mass.
Dr. Warren K. Sinclair, Physics Department, M. D. Anderson Hospital, Houston, Tex.
Dr. L. S. Skaggs, Argonne Cancer Research Hospital, Chicago, Ill.
Dr. Scott W. Smith, Radiological Equipment Section, National Bureau of Standards, Washington, D.C.
Dr. W. S. Snyder, University of Tennessee, Knoxville, Tenn.
Dr. J. N. Stannard, Atomic Energy Project, University of Rochester Medical School, Rochester, N.Y.
*Mr. Murray Stein, Chief, U.S. Public Health Service, Washington, D.C.
Dr. Curt Stern, Department of Zoology, University of California, Berkeley, Calif.
Dr. J. H. Sterner, Medical Director, Eastman Kodak Co., Rochester, N.Y.
Dr. Wellington B. Stewart, Pathology Department, Columbia University, New York, N.Y.
Dr. Robert S. Stone, Medical Center, University of California, San Francisco, Calif.
Dr. John B. Storer, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine.
Dr. Lauriston S. Taylor, Atomic and Radiation Physics Division, National Bureau of Standards, Washington, D.C.
Mr. J. G. Terrill, Jr., Division of Radiation Health, Public Health Service, Washington, D.C.
Dr. C. A. Tobias, Donner Laboratory, University of California, Berkeley, Calif.

*Dr. E. Tochilin, Nuclear Radiation Branch, U.S. Naval Radiological Defense Laboratory, San Francisco, Calif.
Mr. E. Dale Trout, X-ray Department, General Electric Co., Milwaukee, Wis.
*Dr. K. C. Tsien, Temple University Hospital, Philadelphia, Pa.
Dr. Arthur C. Upton, Biology Division, Oak Ridge National Laboratory, Oak Ridge, Tenn.
*Dr. Weber Wallace, Radiation Laboratory, University of California, Berkeley, Calif.
Dr. Shields Warren, Cancer Research Institute, New England Deaconess Hospital, Boston, Mass.
Dr. James L. Weatherwax, Philadelphia, Pa.
Dr. G. N. Whyte, Radiology Laboratory, National Research Council, Ottawa, Ontario, Canada.
Dr. E. G. Williams, Division of Hospital and Medical Facilities, U.S. Public Health Service, Washington, D.C.
Dr. M. M. D. Williams, Mayo Clinic, Rochester, Minn.
Capt. S. F. Williams (MC), USN, Radiology Section, National Naval Medical Center, Bethesda, Md.
Dr. Harold O. Wyckoff, Radiation Physics Laboratory, National Bureau of Standards, Washington, D.C.
Dr. Rosalyn Yalow, Veterans' Administration Hospital, Bronx, N.Y.
*Dr. Raymond E. Zirkle, University of Chicago, Chicago, Ill.

Appendix A–3

Maximum Permissible Radiation Exposures to Man [1]

Introduction

On January 8, 1957, the National Committee on Radiation Protection and Measurements issued a Preliminary Statement setting forth its revised philosophy on Maximum Permissible Radiation Exposures to Man.[2] Since that time several of the NCRP subcommittees have been actively studying the necessary revisions of their respective handbooks. These studies have shown the need for (1) clarification of the earlier statement and (2) modification or extension of some of the concepts in that statement. Furthermore, the International Commission on Radiological Protection has made minor changes in their recommendations. Accordingly the NCRP has prepared a set of guides, given below, that will assure uniformity in the basic philosophy to be embodied in the various handbooks. Since many of the handbooks are followed closely in planning radiation operations in the United States, and since the modification of a handbook may require many months of effort, it seems wise to make the overall guiding principles available in advance of the reissuance of the revised handbooks. These guides are not designed to take the place of any of the handbooks; the principles given below will be extensively treated later in appropriate places. In the meantime handbook revisions or supplementary statements will be issued as rapidly as possible.

Since the statement of an average per capita dose for the whole population does not directly influence the substance of the NCRP Handbooks, no further statements regarding such a number will be made at this time. In any discussion of the MPD it is impractical to take into consideration the dose from natural background and medical or dental procedures.

The changes in the accumulated MPD are not the result of positive evidence of damage due to use of the earlier permissible dose levels, but rather are based on the desire to bring the MPD into accord with the trends of scientific opinion; it is recognized that there are still many uncertainties in the available data and information. Consideration has also been given to the probability of a large future increase in radiation uses. In spite of the trends, it is believed that the risk involved in delaying the activation of these recommendations is very small if not negligible. Conditions in existing installations should be modified to meet the new recommendations as soon as practicable, and the new MPD limits should be used in the design and planning of future apparatus and installations. Because of the impact of these changes and the time required to modify existing equipment and installations, it is recommended on the basis of present knowledge that a

[1] Addendum to National Bureau of Standards Handbook 59, "Permissible Dose From External Source of Ionizing Radiations" (extends and replaces insert of January 8, 1957).
[2] NBS Tech. News Bul. 41, 17 (February 1957).

conversion period of not more than 5 years from January 1957 (see footnote 1) be adopted within which time all necessary modifications should be completed.

The basic rules and the operational guides outlined below are intended to be in general conformity with the philosophy expressed in the 1953 statement of the ICRP, as revised in April 1956 and March 1958.

GUIDES FOR THE PREPARATION OF NCRP RECOMMENDATIONS

It is agreed that we should make clear distinction between basic MPD *rules* or requirements, and operational or administrative *guides* to be used according to the special requirements in any particular situation. Guides have the distinct value of retaining some reasonable degree of uniformity in the interpretation of the basic rules.

The risk to the individual is not precisely determinable but, however small, it is believed not to be zero. Even if the injury should prove to be proportional to the amount of radiation the individual receives to the best of our present knowledge, the new permissible levels are thought not to constitute an unacceptable risk. Since the new rules are designed to limit the potential hazards to the individual and to the reproductive cells, it is therefore, necessary to control the radiation dose to the population as a whole, as well as to the individual. For this reason, maximum permissible doses are set for the small percentage of the whole population who may be occupationally exposed, in order that they not be involved in risks greater than are normally accepted in industry. Also radiation workers represent a somewhat selected group in that individuals presumably of the greatest susceptibility (i.e., infants and children) are not included. However, for the persons located immediately outside of controlled areas but who may be exposed to radiation originating in controlled areas, the permissible level is adjusted downward from that in the controlled area because the number of such persons may not be negligible. With this downward adjustment, the risk to the *individual* is negligible so that small transient deviations from the prescribed levels are unimportant.

Controls of radiation exposure should be adequate to provide reasonable assurance that recommended levels of maximum permissible dose shall not be exceeded. In addition, the NCRP reemphasizes its long-standing philosophy that radiation exposures from whatever sources should be as low as practical.

DEFINITIONS

For the purposes of these guides, the following definitions are given:

Controlled area.—A defined area in which the occupational exposure of personnel to radiation or to radioactive material is under the supervision of an individual in charge of radiation protection. (This implies that a controlled area is one that requires control of access, occupancy, and working conditions for radiation protection purposes.)

Workload.—The output of a radiation machine or a radioactive source integrated over a suitable time and expressed in appropriate units.

Occupancy factor.—The factor by which the workload should be multiplied to correct for the degree or type of occupancy of the area in question.

RBE dose.—RBE stands for relative biological effectiveness. An RBE dose is the dose measured in rems. (This is discussed in the report of the International Commission on Radiological Units and Measurements, 1956, NBS Handbook 62, p. 7.)

BASIC RULES

1. Accumulated dose (radiation workers)

A. External exposure to critical organs.—

Whole body, head and trunk, active blood-forming organs, or gonads: The maximum permissible dose (MPD), to the most critical organs, accumulated at any age, shall not exceed 5 rems multiplied by the number of years beyond age 18, and the dose in any 13 consecutive weeks shall not exceed 3 rems.[3]

Thus the accumulated MPD$=(N-18)\times 5$ rems, where N is the age in years and is greater than 18.

Comment: This applies to radiation of sufficient penetrating power to affect a significant fraction of the critical tissue. (This will be enlarged upon in the revision of H59.)

[3] The quarterly limitation of 3 rems in 13 weeks is basically the same as in H59 except that it is no longer related to the old weekly dose limit. The yearly limitation is 12 rems instead of the 15 rems as given in the NCRP preliminary recommendations of January 8, 1957.

B. External exposure to other organs.—

Skin of whole body: MPD=10 (N–18) rems, and the dose in any 13 consecutive weeks shall not exceed 6 rems.[4]

Comment: This rule applies to radiation of low penetrating power. See figure 2, H59.

Lens of the eyes: The dose to the lens of the eyes shall be limited by the dose to the head and trunk (A, above).

Hands and forearms, feet and ankles: MPD=75 rems/year, and the dose in any 13 consecutive weeks shall not exceed 25 rems.[5]

C. Internal exposures.—The permissible levels from internal emitters will be consistent as far as possible with the age-proration principles above. Control of the internal dose will be achieved by limiting the body burden of radioisotopes. This will generally be accomplished by control of the average concentration of radioactive materials in the air, water, or food taken into the body. Since it would be impractical to set different MPC values for air, water, and food for radiation workers as a function of age, the MPC values are selected in such a manner that they conform to the above-stated limits when applied to the most restrictive case, viz, they are set to be applicable to radiation workers of age 18. Thus, the values are conservative and are applicable to radiation workers of any age (assuming there is no occupational exposure to radiation permitted at age less than 18). The factors entering into the calculations will be dealt with in detail in the forthcoming revision of Handbook 52.

The maximum permissible average concentrations of radionuclides in air and water are determined from biological data whenever such data are available, or are calculated on the basis of an average annual dose of 15 rems for most individual organs of the body,[6] 30 rems when the critical organ is the thyroid or skin, and 5 rems when the gonads or the whole body is the critical organ. For bone seekers the maximum permissible limit is based on the distribution of the deposit, the RBE, and a comparison of the energy release in the bone with the energy release delivered by a maximum permissible body burden of 0.1 μg Ra^{226} plus daughters.

2. Emergency dose (radiation workers)

An accidental or emergency dose of 25 rems to the whole body or a major portion thereof, occurring only once in the lifetime of the person, need not be included in the determination of the radiation exposure status of that person (see p. 69, H59).[7]

3. Medical dose (radiation workers)

Radiation exposures resulting from necessary medical and dental procedures need not be included in the determination of the radiation exposure status of the person concerned.[7]

4. Dose to persons outside of controlled areas

The radiation or radioactive material outside a controlled area, attributable to normal operations within the controlled area, shall be such that it is improbable that any individual will receive a dose of more than 0.5 rem in any 1 year from external radiation.

The maximum permissible average body burden of radionuclides in persons outside of the controlled area and attributable to the operations within the controlled area shall not exceed one-tenth of that for radiation workers.[8] This will normally entail control of the average concentrations in air or water at the point of intake, or rate of intake to the body in foodstuffs, to levels not exceeding one-tenth of the maximum permissible concentrations allowed in air, water, and foodstuffs for occupational exposure. The body burden and concentrations of radionuclides may be averaged over periods up to 1 year.

The maximum permissible dose and the maximum permissible concentrations of radionuclides as recommended above are primarily for the purpose of keeping the average dose to the whole population as low as reasonably possible, and not because of specific injury to the individual.

Comment: Occupancy-factor guides will be needed by several of the subcommittees. It will be important that these do not differ markedly between different handbooks. The Executive Committee will endeavor to establish a set of uniform occupancy-factor guides.

[4] This is similar to the 1954 (H59) recommendations in that the permissible skin dose is double the whole-body dose. H59 made no statement regarding a 13-week limitation.
[5] This is basically the same as the 1954 (H59) recommendations except for the 13-week limitation.
[6] This is basically the same as the 1953 (H52) recommendations.
[7] This is the same as the 1954 (H59) recommendations.
[8] This is basically the same as the recommendations of January 8, 1957.

OPERATIONAL AND ADMINISTRATIVE GUIDES

5. The maximum dose of 12 rems in any 1 year as governed by the 13-week limitation, should be allowed only when adequate past and current exposure records exist. The allowance of a dose of 12 rems in any 1 year should not be encouraged as a part of routine operations; it should be regarded as an allowable but unusual condition. The records of previous exposures must show that the addition of such a dose will not cause the individual to exceed his age-prorated allowance.

6. The full 3-rem dose should not be allowed to be taken within a short time interval under routine or ordinary circumstances (however, see paragraph 2 on Emergency Dose above.) Desirably, it should be distributed in time as uniformly as possible and in any case *the dose* should not be greater than 3 rems in any 13 consecutive weeks. When the individual is not personally monitored and/or personal exposure records are not maintained, the exposure of 12 rems in a year should not be allowed; the yearly allowance under these circumstances should be 5 rems, provided area surveys indicate an adequate margin of safety.

7. When any person accepts employment in radiation work, it shall be assumed that he has received his age-prorated dose up to that time unless (1) satisfactory records from prior radiation employment show the contrary, or (2) it can be satisfactorily demonstrated that he has not been employed in radiation work. This is not to imply that such an individual should be expected to routinely accept exposures at radiation levels approaching the yearly maximum of 12 rems up to the time he reaches his age-prorated limit. Application of these principles will serve to minimize abuse.

8. The new MPD standards stated above are not intended to be applied retroactively to individuals exposed under previously accepted standards.

9. It is implicit in the establishment of the basic protection rules that at present it is neither possible nor prudent to administer a suitably safe radiation protection plan on the basis of yearly monitoring only. It is also implicit that at the low permissible dose levels now being recommended, there is fairly wide latitude in the rate of delivery of this dose to an individual so long as the dose remains within the age-prorated limits specified above. In spite of a lack of clear evidence of harm due to irradiation at dose rates in excess of some specified level, it is prudent to set some reasonable upper limit to the rate at which an occupational exposure may be delivered. Therefore, it has been agreed that the dose to a radiation worker should not exceed 3 rems in any 13 consecutive weeks.

10. The latitude that may appropriately be applied in the operational and administrative control or occupational exposure will be dictated by two major factors (*a*) the type of risk involved and the likelihood of the occurrence of overexposures and (*b*) the monitoring methods, equipment, and the dose-recording procedures available to the radiation users. Where the hazards are minimal and not likely to change from day to day or where there are auxiliary controls to insure that the 13-week limitation will not be exceeded, the integration may be carried out over periods up to 3 months. Where the hazards are significant and where the exposure experience indicates unpredictability as to exposure levels, the doses should be determined more frequently, such as weekly, daily, hourly, or oftener, as may be required to limit the exposure to permissible values.

11. For the vast majority of installations (medical and industrial), operation is more or less routine and reasonably predictable and it may be expected that their monitoring procedures will be minimal. For such installations the protection design should be adequate to insure that overexposures will not occur—otherwise frequent sampling tests should be specified. Where film badges are used for monitoring, it is preferable that they be worn for 4 weeks or longer, since otherwise the inaccuracy of the readings may unduly prejudice the radiation history of the individual. Where operations are not routine or are subject to unpredictable variations that may be hazardous, self-reading pocket dosimeters, pocket chambers, or other such devices should also be worn and should be read daily or more often as circumstances dictate.

12. Except for planning, convenience of calculation, design, or administrative guides, the NCRP will discontinue the use of a weekly MPD or MPC.[9]

13. The Committee has deliberately omitted the discussion of future exposure forfeiture for exposures exceeding the MPD on the grounds that any such statements might lend encouragement to the unnecessary use of forfeiture provisions.

APRIL 15, 1958.

[9] This represents a minor change from the NCRP recommendations of January 8, 1957, but no change in the basic MPD.

APPENDIX B–1

U.S. ATOMIC ENERGY COMMISSION—AEC MANUAL

TN–0000–198

TRANSMITTAL NOTICE

CHAPTER 0524. PERMISSIBLE LEVELS OF RADIATION EXPOSURE

1. Attached is Chapter 0524 of the AEC Manual, title as above.
2. This chapter establishes rules governing the AEC and AEC contractors with respect to levels of radiation exposure to be used as the maximum permissible occupational exposure for their personnel and other persons who may be exposed to radiation originating from AEC operations.
3. Personnel engaged in weapons tests at the Nevada Test Site or Eniwetok Proving Grounds are not covered by this chapter. Limits of exposure for them and the general population are the subject of separate authorizations.
4. Please file this Chapter in Part 0500, "Health and Safety," of your AEC Manual.

R. W. COOK, *Deputy General Manager.*

January 9, 1958.
Effective: February 1, 1958.

Volume: 0000 General Administration.
Part: 0500 Health and Safety.

CHAPTER 0524 PERMISSIBLE LEVELS OF RADIATION EXPOSURE

0524–01 *Purpose and Scope*

This chapter establishes rules governing the AEC and AEC contractors with respect to levels of radiation exposure for their personnel (exclusive of those actually engaged in weapons tests) and other persons who may be exposed to radiation from AEC and AEC contractor operations, and assigns responsibility for compliance with these levels. In those instances where a contractor is also an AEC licensee, the contract relationships will not exempt him from compliance with this directive and the terms of his license. Accordingly, such contractor-licensee will normally be obligated to conduct his radiation protection activities under his license in accordance with AEC regulation 10 CFR, Part 20, "Standards for Protection Against Radiation."

0524–02 *Policy*

The Commission has adopted the recommendations of the National Committee on Radiation Protection and Measurement (NCRP), entitled "Maximum Permissible Radiation Exposures to Man," issued by the NCRP, dated January 8, 1957, except as modified by d. below. (See appendix AEC 0524–02–A).[1] The Committee's recommendation[2] shall be wholly complied with by AEC and AEC contractor personnel except that the following instructions shall be applied in the interpretation of these recommendations:

a. Where it is necessary to modify presently existing conditions in order to comply with these recommendations for permissible exposure and a conversion period has been requested by an appropriate AEC official, an applicable conversion period not to exceed five years will be determined by agreement among the Division of Biology and Medicine, appropriate Headquarters Divisions, and Operations Offices.

b. Exposure in excess of a recommended maximum permissible level does not in and of itself constitute an injury in the clinical sense.

c. Accumulation of dose for the year 1958, and thereafter until such time as the rule may be modified, shall be guided by recommendation No. 1 of appendix 0524–02–A which states that the maximum permissible accumulated dose in rems at any age, is equal to 5 times the number of years beyond age 18, provided no annual increment exceeds 15 rems. That is, MPD, 5 (N–18) where N is the "effective age" on December 31 of any year. Effective age shall be taken as the age actually attained between April 1 of that

[1] These NCRP recommendations modify the basic standards listed in AEC Manual Chapter 0550–051.
[2] The NCRP recommendations basically applicable to AEC and AEC contractor operations are summarized in appendix 0524–02–F, table I, "Recommended Limits on Exposure to External Radiation," and appendix 0524–02–G, table II, "Recommended Limits on Exposure to Internal Radiation (illustrative examples)."

year and March 31 of the following year, both dates inclusive. It should be noted that proposed regulations of the Secretary of Labor prohibit the employment in radiation work by industries engaged in interstate commerce of persons below the attained age of 18. Recommendation No. 1 also states that the value for the maximum permissible accumulated dose to the skin (of the whole body) is double the value for whole body and critical organs. When the dose only to the extremities is concerned, the maximum permissible accumulated dose is 75 rems per year. Note also paragraph 9, of appendix 0524–02–A regarding previous radiation exposure experience.

d. The previously recommended limits for weekly and 13-week whole-body dose are superseded by the provision that not more than one-fourth of the 15 rems maximum permissible yearly dose shall be taken in one-fourth of a year.[3] [4]

e. For internal emitters which have the whole body or the gonad as the critical organ, the MPC's (Maximum Permissible Concentrations) listed in NBS Handbook No. 52 are reduced by a factor of 3. All others remain as listed, pending a major revision of the Handbook.

f. Routine medical and dental exposures are not to be considered as part of the record of occupational exposures. Under extraordinary circumstances, the physician in charge may wish to make some recommendation regarding restriction of routine occupational exposure.

g. It is recognized that recommendation No. 5 of appendix 0524–02–A is wholly acceptable as a statement of philosophy and is endorsed as such by the Commission. However, AEC cannot influence the quantity of radiation received by the population as a whole from all sources of radiation, but can exercise control over the release of radioactive materials to the general environment from AEC operations. Therefore, when the exposure of population groups outside of controlled areas is considered, radioactive effluents from AEC operations shall not be released to the environment in amounts which might be expected to expose such members of the general population to more than an average whole body dose of 0.5 rem [5] [6] per year or to an average concentration of radioactive materials in air and water greater than $\frac{1}{10}$ of the maximum permissible concentrations (MCP's) recommended by the NCRP for occupational exposure.[7] When there is a reasonable expectation that the average radiation dose to any individual in a population group outside of controlled areas might approach either of the above limits, adequate radiation measurements shall be made in those areas so occupied.

0524–03 *Responsibilities*

031 Directors of Divisions and Offices, Headquarters, are responsible for interpreting and applying the instructions of section 0524–02 above to AEC employees and Operations Offices under their jurisdiction.

032 Managers of Operations are responsible for interpreting and applying the instructions of section 0524–02 above for permissible exposure to radiation so that those operations under their jurisdiction shall fully comply with these instructions and shall maintain a level of performance consistent with them.

Maximum Permissible Radiation Exposures to Man

A preliminary statement of the National Committee on Radiation Protection and Measurement, January 8, 1957

INTRODUCTION

Since the publication of NBS Handbook 59 on "Permissible Dose from External Sources of Ionizing Radiation," the National Committee on Radiation Protection and Measurement (NCRP) has continued the study and review of its recommendations, particularly with respect to genetic effects and the possible shortening of average life expectancy due to radiation exposure of a larger fraction of the popu-

[3] This recommendation proposed by the NCRP Executive Committee at its November 18, 1957, meeting is adopted in advance of formal approval and issuance by the Main Committee. It is noted, therefore, that if there are differences between the proposed and approved recommendation it may be necessary to make appropriate amendment to the provisions of this chapter.

[4] Limits of exposure of personnel involved in the actual conduct of weapons tests in Nevada or in the Pacific Proving Ground are the subject of separate authorization.

[5] Since maximum permissible occupational exposure criteria are herein applied in accordance with recommendation No. 4 of appendix 0524–02–A, radiation exposures from necessary medical and dental procedures shall not be allowed for in the determination of this average whole body dose.

[6] The value 0.5 rem is consistent with the suggestion in paragraph 12 of appendix 0524–02–A.

[7] Limits of exposure of the population from weapons tests in Nevada or in the Pacific Proving Ground will be the subject of a separate authorization.

lation. The NCRP proposals resulting from these studies had an important influence on the decisions reached by the International Commission on Radiological Protection (ICRP) in Geneva in April 1956, which resulted in a general lowering of the maximum permissible accumulated dose (MPD) for occupational radiation exposures, as well as for exposures of the population as a whole. These changes are in accord with the informal agreements reached by the ICRP in Stockholm in 1952.

The NCRP has now agreed upon the formulation of revised recommendations on maximum permissible doses which integrate the national and international views for practical application. The Committee is pleased to note that the findings of the ICRP are reinforced by the important information and data provided in the subsequent reports of the National Academy of Sciences and the British Medical Research Council.

The changes in the accumulated MPD are not the results of positive evidence of damage due to use of the earlier permissible dose levels, but rather are based on the desire to bring the MPD into accord with the trends of scientific opinion; it is recognized that there are still many uncertainties in the available data and information. Consideration has also been given to the probability of a large future increase in radiation uses. In spite of the trends, it is believed that the risk involved in delaying the activation of these recommendations is very small if not negligible. Conditions in existing installations should be modified to meet the new recommendations as soon as practicable, and the new MPD limits should be used in the design and planning of future apparatus and installations. Because of the impact of these changes and the time required to modify existing equipment and installations, it is recommended on the basis of present knowledge that a conversion period of not more than five years be adopted within which time all necessary modifications should be completed.

DEFINITIONS

For the purposes of this preliminary statement, the following tentative definitions are given:

Controlled area.—A defined area in which the occupational exposure of personnel to radiation or to radioactive material is under the supervision of a radiation safety officer. (This implies that a controlled area is one that requires control of access, occupancy, and working conditions for radiation protection purposes.)

Workload.—The output of a radiation machine or a radioactive source integrated over a suitable time and expressed in appropriate units.

Occupancy factor.—The factor by which the workload should be multiplied to correct for the degree or type of occupancy of the area in question.

RBE dose.—RBE stands for relative biological effectiveness. An RBE dose is the dose measured in rems. (This is discussed in the forthcoming report of the International Commission on Radiological Units and Measurement.)

MPD RECOMMENDATIONS FOR OCCUPATIONAL CONDITIONS (CONTROLLED AREAS)

1. *Accumulated dose.*—The maximum permissible accumulated dose, in rems, at any age, is equal to 5 times the number of years beyond age 18, provided no annual increment exceeds 15 rems. Thus the accumulated MPD=5 (N–18) rems where N is the age and greater than 18. This applies to all critical organs except the skin, for which the value is double.

2. *Weekly dose.*—The previous permissible weekly whole-body dose of 0.3 rem, and the 13-week dose of 3 rems when the weekly limit is exceeded are still considered to be the weekly MPD with the above restriction for accumulated dose.

3. *Emergency dose.*—An accidental or emergency dose of 25 rems to the whole body, occurring only once in the lifetime of the person, shall be assumed to have no effect on the radiation tolerance status of that person. (See National Bureau of Standards Handbook 59.)

4. *Medical dose.*—Radiation exposures resulting from necessary medical and dental procedures shall be assumed to have no effect on the radiation tolerance status of the person concerned.

MPD RECOMMENDATIONS FOR THE WHOLE POPULATION

5. The maximum permissible dose to the gonads for the population of the United States as a whole from all sources of radiation, including medical and other manmade sources, and background, shall not exceed 14 million rems per million of population over the period from conception up to age 30, and one-third that

amount in each decade thereafter. Averaging should be done for the population group in which crossbreeding may be expected.

RECOMMENDATIONS FOR INTERNAL EMITTERS

6. In controlled areas, the permissible radiation levels for internal emitters will conform to the general principles outlined above. Where the critical organ is the gonad or the whole body, the maximum permissible concentrations of radionuclides in air and water will be one-third the values heretofore specified for radiation workers. Where single organs other than the gonads are regarded as the critical organ, the present maximum permissible concentrations will continue. For individuals outside of controlled areas, the maximum permissible concentrations should be one-tenth of those for occupational exposures. (Other changes in the maximum permissible concentrations for radionuclides may be introduced because of additional information developed since the publication of National Bureau of Standards Handbook 52.)

DISCUSSION OF REVISED RECOMMENDATIONS

7. The MPD for occupational exposure is based on the absence of detectable injury to the individual. It remains at its present level of 0.3 rem/week for the whole body. Where the dose in any week exceeds this value, a dose of 3 rems in 13 weeks may be accepted. The 13-week period may start at the beginning of the calendar quarter or the beginning of the week during which the permissible weekly dose was exceeded.

8. The rules given in Handbook 59 will be continued for operational and administrative purposes, but some of the rules will be modified by provisions related to an average yearly limitation of occupational exposure to external sources of ionizing radiation of 5 rems to the blood-forming organs, gonads, and lens of the eyes, and of 10 rems to the skin. The use of "5 rems" in the statement of the revised rules is for the purpose of design and administration. The critical limitation will be that defined for the total accumulated dose in paragraph 1 above.

9. If a person's occupational exposure is documented or otherwise known with reasonable certainty, he may be permitted to use his reserve exposure in accordance with paragraphs 1 and 2 above. In all other cases, he shall be assumed to have received his maximum accumulated dose as indicated in paragraph 1 above.

10. It is considered that with the current and proposed low levels of occupational exposure, it is presently not necessary to make special allowance for medical exposure in conjunction with occupational exposure. This consideration may later become important. The effects of medical exposures have long been considered by this committee to be the responsibility of the attending physician; it is his responsibility to evaluate medical radiation exposure in relation to the health of the individual. (See National Bureau of Standards Handbook 59.)

11. In the determination of the population dose in the vicinity of radiation sources, proper consideration should be given to occupancy factor and to workload. The exposure of individuals outside of controlled areas may be integrated over periods up to 1 year.

12. While at the moment it is not feasible to determine the average exposure for the population with any reasonable accuracy, the adoption of some figure is necessary for planning purposes. For the immediate future, it may be assumed that the total integrated RBE dose received by all radiation workers will be small in comparison with the integrated RBE dose of the whole population. Furthermore, persons outside of controlled areas, but exposed to radiation from a controlled area, constitute only a small portion of the whole population. Therefore, if this small portion is assumed to receive yearly an average per capita dose of 0.5 rem, the total dose to the whole population from man-made radiations is not likely to exceed 10 million rems per million of population up to age 30. (This assumes a dose of 4 million rems per million of population over this age period from background radiation.)

TABLE I.—*Recommended limits on exposure to external radiation*

Exposure	National Committee on Radiation Protection and Measurement	
	Previous	New
OCCUPATIONAL		
Critical organs (includes the whole body, blood-forming organs, gonads, lenses of the eyes).	0.3 rem/week 3 rems/quarter [2] 15 rems/year [3]	([4]). ([5]). 5 rems/year.[6] 15 rems/year.[7]
Skin (whole body)	0.6 rem/week 30 rems/year [3]	([4]). 10 rems/year.[6 8] 30 rems/year.[7 9]
Extremities (skin dose)	1.5 rems/week [4]	75 rems/year.[9]
NONOCCUPATIONAL		
Individuals in vicinity of controlled areas [1] General populations (average exposure to gonads above background from all sources).	1.5 rems/year 45 rems/0–30 years (1.5 rems/year).	0.5 rem/year (average). 10 rems/0–30 years (3.3 rems/decade after age 30).

[1] Exposure resulting from plant operation, not including background or medical exposure.
[2] If 0.3 rem/week is exceeded.
[3] Assumes 50 workweeks per year.
[4] It is expected that modification of the NCRP recommendations will result in the dropping of a weekly limitation
[5] It is expected that modification of the NCRP recommendation will result in the establishment of the quarterly limit at 3.75 rems.
[6] Average dose/year lifetime occupational.
[7] Maximum in 1 year.
[8] Double the MPD for critical organs.
[9] Assumes 50 workweeks per year.

TABLE II.—*Recommended limits on exposure to internal radiation (illustrative examples)*

Exposure	National Committee on Radiation Protection and Measurement	
	Previous	New
OCCUPATIONAL		
Adult skeleton	0.1 μc Ra–226 1.0 μc Sr–90	0.1 μc Ra–226. 1.0 μc Sr–90.
Whole body and gonads	15.0 μc Na–24 10^4 μc H–3	5.0 μc Na–24. 3.3×10^3 μc H–3.
NONOCCUPATIONAL		
Skeleton	0.01 μc Ra–226 0.1 μc Sr–90	0.01 μc Ra–226. 0.1 μc Sr–90.
Whole body and gonads	1.5 μc Na–24 10^3 μc H–3	0.5 μc Na–24. 3.3×10^2 μc H–3.

APPENDIX B–2

U.S. ATOMIC ENERGY COMMISSION—AEC MANUAL

TN 0000–212

TRANSMITTAL NOTICE

CHAPTER 0525 OCCUPATIONAL RADIATION EXPOSURE INFORMATION FOR AEC AND AEC CONTRACTOR EMPLOYEES

1. Attached is Chapter 0525, title as above.

2. This chapter establishes the policy, scope and procedures for the communication to AEC and AEC contractor employees of recorded information concerning their occupational radiation exposure received during employment in AEC operations.

3. It should be noted that if an AEC contractor also conducts work pursuant to an AEC license, his employees whose accumulated exposure is from both con-

tract and license activities shall be informed of their total radiation exposure in accordance with the provisions of this chapter.

4. Please file this chapter in Part 0500 of your AEC Manual.

R. E. HOLLINGSWORTH,
(For R. W. Cook, *Deputy General Manager*).

MAY 13, 1958. Effective: May 13, 1958.

Volume: 0000 General Administration.
Part: 0500 Health and Safety.

CHAPTER 0525 OCCUPATIONAL RADIATION EXPOSURE INFORMATION FOR AEC AND AEC CONTRACTOR EMPLOYEES

0525–01 *Purpose*

This Chapter establishes the policy, scope and procedures for the communication to AEC and AEC contractor employees of recorded information concerning their occupational radiation exposure received during the period of their employment.

0525–02 *Policy*

It is the policy of AEC that AEC and AEC contractor employees be informed of occupational radiation exposure which has been recorded as having been received by them during employment in the AEC program.

0525–03 *Scope*

Where the employer is an AEC contractor his employees are to be informed of their radiation exposure from the contract work as specified in Section –05, below. If such an employer also conducts noncontract work involving the handling of radioactive materials pursuant to the terms of an AEC license, his employees are to be informed of their total radiation exposure from both the contract and license work as specified in Section –05, below.

0525–04 *Responsibilities*

041 Heads of Divisions and Offices, Headquarters, and Managers of Operations are responsible for determining that in AEC and AEC contractor operations under their jurisdiction, all employees are:

a. advised of the provisions of this Chapter and,

b. informed of their recorded occupational radiation exposure in accordance with the uniform practices specified in this Chapter, except as provided in Subsection 042 below.

042 The Director, Division of Biology and Medicine, is responsible for informing AEC Headquarters employees of their recorded radiation exposure in accordance with the uniform practices specified in this Chapter.

0525–05 *Uniform Practices*

051 Information entered in an employee's occupational radiation exposure record (exclusive of medical exposures) [1] shall be made available to him at his request. A reasonable period of time shall be allowed his employer for the preparation of such information.

052 Each employee for whom radiation exposure records are maintained shall be informed within thirty days after the close of the calendar year of his total recorded whole body radiation exposure dose from external penetrating radiation accumulated during the prior calendar year just ended, if the permissible yearly exposure as specified in AEC Manual Chapter 0524, PERMISSIBLE LEVELS OF RADIATION EXPOSURE, has been exceeded.

053 An employee shall be notified immediately of his recorded radiation exposure following the determination, by any technique acceptable to the Division of Biology and Medicine, that the employee has received a recorded accumulated radiation exposure exceeding any of the following limits specified in AEC Manual Chapter 0524:

a. in any calendar year quarter the quarterly permissible dose for external penetrating radiation to the whole body;

b. in any calendar year the yearly permissible dose for external penetrating radiation to the whole body;

c. a quantity of any radioisotope (whose effective half life is 180 days or greater) in the body estimated to be greater than the maximum permissible amount of radioisotope in the total body; or

[1] See AEC Manual Chapter paragraph 0524-02f.

d. a quantity of any radioisotope in the body resulting in a calculated dose in rads to any organ exceeding the yearly permissible dose for that organ.

054 Any employee terminating his employment shall at his request be provided with a written summary of his cumulative recorded occupational radiation exposure received during the period of his employment.

APPENDIX B–3

U.S. ATOMIC ENERGY COMMISSION AEC MANUAL

TN–0000–237

TRANSMITTAL NOTICE

CHAPTER 0523 RADIATION EXPOSURE REPORTS

1. Attached is Chapter 0523.
2. This chapter establishes requirements for reporting radiation exposures from the utilization of radioactive materials or from the use of ionizing radiation generating equipment.
3. Filing instructions:
   a. Please file the attached chapter in Part 0500 of your Manual.
   b. File this Transmittal Notice in Volume 0000.

R. E. HOLLINGSWORTH,
(For General Manager).

Effective: October 10, 1958.
Revised: October 10, 1958.

Volume: 0000 General Administration.
Part: 0500 Health and Safety.

CHAPTER 0523 RADIATION EXPOSURE REPORTS

0523–01 *Purpose*

This chapter establishes requirements for reporting radiation exposures which result from the handling and utilization of radioactive materials or from the use of ionizing radiation generating equipment.

0523–02 *Policy*

The Atomic Energy Commission must be informed and records must be kept by AEC and AEC contractor operations of radiation exposures received by individuals as a result of AEC activities, and of the effectiveness of its radiological protection program.[1]

0523–03 *Scope*

Reporting requirements extend to activities subject to the authority of the Atomic Energy Commission. They do not extend to the medical aspects of alleged radiation exposure injury (see Chapter 0521, "Medical Investigation of Alleged Disabilities from Special Hazards"); nor to exposures which result—

a. under the operation of licenses which are governed by Chapter 0707, "Investigation of Radiation Incidents Involving Licensed Material; 10 CFR 20, "Standards for Protection Against Radiation", and license provisions; except that where the exposure results from both contract and license activities, the combined exposure shall be reported;

b. from weapons testing activities covered by special instructions;

c. from the use of radiation generating equipment by a recipient of an AEC grant or contribution;[2] or

d. from the use of radiation or radioactive materials for medical procedures. (See AEC Chapter 0524–02f and Appendix 0524–02–C, 4.)

0523–04 *Responsibilities*

041 *Heads of Divisions and Offices, Headquarters*, are responsible for—

a. forwarding to the Divisions of Biology and Medicine, Inspection, Finance, Information Services, and Office of Industrial Relations, those reports required by Section 0523–05; and

---

[1] An AEC Manual Chapter will be published establishing minimum standards of performance, uniform procedures and criteria for recording and maintaining personnel radiation exposure records.

[2] This refers to assistance obtained under programs similar to Grants for Equipment for Nuclear Science and Engineering Education and Grants for Nuclear Training in Life Sciences.

b. advising the Office of Congressional Liaison, Headquarters, that the JCAE be informed of significant radiation exposures. (See AEC Manua Chapter Subsection 0292–046.)

042 *The Director, Division of Biology and Medicine,* is responsible for—

a. the development and administration of policy and procedures for the submission of reports on the radiation exposure of AEC and AEC contractor employees and other individuals; and

b. informing the General Manager, Division of Information Services, and Office of Industrial Relations of reports of radiation exposures defined in subsection 0523–052, Special Reports.

043 *The Director, Division of Licensing and Regulation,* and *Director, Division of Inspection,* are responsible for making available to the Director, Division of Biology and Medicine, all radiation exposure information reported by licensees or obtained through investigations.

044 *Managers of Operations* are responsible for—

a. notifying Headquarters as soon after the occurrence as possible (by telephone or teletype) of radiation exposures specified in subsection 0523–052;

b. forwarding summary reports of radiation exposure information specified by Section 0523–05 obtained from AEC employees and AEC contractors to the Director, Division of Biology and Medicine, through channels; and

c. providing assistance to the Director, Division of Biology and Medicine, in obtaining additional information on radiation exposures reported in accordance with Section 0523–05, and radiation exposure information required for special studies or reports but not reported in accordance with this Chapter.

0523–05 *Reports*

051 *Annual Reports.*—A report shall be submitted to the Director, Division of Biology and Medicine, through channels, prior to February 28 each year, summarizing external and internal radiation exposures recorded during the previous calendar year for AEC and AEC contractor personnel in the course of AEC activities. (See Appendix 0523–051–A, Reporting Guide.)

a. All radiation exposure values shall be estimated by the most generally accepted methods and instrumentation available for use at the installation reporting. For whole body dose from external penetrating radiation it is not expected that depth dose calculations be made but, rather, the radiation dose measured at or near the body surface by the personnel meter used (e. g., film badge, dosimeter, or pocket ionization chamber) is adequate, and for internal body deposition on the basis of the best biological data available taking into account the circumstances of the specific exposure.

b. This report shall be prepared in summary form and exposure information from each AEC and AEC contractor installation reporting shall be identified with its originator.

c. External whole body exposures [3] to penetrating radiation (e.g., X-ray, gamma, neutron) shall be reported in rem units (see AEC Appendix 0523–051–B) which may be determined by applying the appropriate RBE factors recommended by the NCRP in NBS Handbooks No. 59, "Permissible Dose from External Sources of Ionizing Radiation," and No. 63, "Protection Against Neutron Radiation Up to 30 Million Electron Volts," and shall include—

1. the approximate number of employees for whom radiation exposure monitoring is not required;

2. the number of individuals for whom there has been recorded an estimated yearly accumulated occupational radiation exposure to penetrating radiation falling within each of the ranges 0–1, 1–2, 2–3, etc., total rem (e.g., an individual whose yearly dose is 999 mrem would fall in the 0–1 range but a yearly does of 1,000 mrem would fall in the 1–2 rem range);

3. for each individual whose recorded estimated yearly accumulated occupational radiation exposure to penetrating radiation is greater than 15 rem there shall be submitted additional information including that outlined in Appendix 0523–051–D; and

4. information regarding the method used to measure and estimate rem dose values reported in accordance with this Section. (It is not

[3] The use of rem units is necessary since permissible levels of radiation exposure (see AEC Chapter 0524) are expressed in terms of rem units.

necessary to give details for each estimated rem dose when general methods apply.)

d. Internal radiation exposures from radioactive material deposited in the body [4] reported (see AEC Appendix 0523–051–C) shall include—

1. the number of cases of internal deposition of radio-active materials in the body where on the basis of the best biological data available it has been estimated that for a period of six consecutive months the deposition of any radioactive material has averaged greater than one-half of a permissible amount in the body (specified by AEC Manual Chapter paragraph 0524–02e);

2. the number of estimated internal body depositions specified in paragraph 051 d 1 above (giving the total number new and total number previously reported) that have been determined to be of specific as well as unidentified radioactive isotopes (e.g., uranium, plutonium, tritium, polonium, radium, fission products, iodine 131);

3. for each internal body deposition reported in paragraph 051 d 1, above, additional information including that outlined in Appendix 0523–051–E;

4. additional information on previously reported cases of internal exposure; and

5. at the option of the reporter, pertinent information on exposures lower than that specified in paragraph 051 d 1, above.

052 *Special Reports.*—Unless required by AEC Manual Chapter Section 0502–05, Managers of Operations shall submit reports specified below on radiation exposures as follows:

a. An immediate report (by telephone or teletype) to the Operating Division Director, Headquarters, of any occurrence related to AEC or AEC contractor activities subject to the provisions of this Chapter and involving those circumstances specified below. If notification is by telephone, the Director, Division of Biology and Medicine, shall also be notified by telephone. Reports by telephone shall be confirmed the same day by teletype with copies to the Headquarters Divisions of Inspection, Finance, and Information Services; and the Office of Industrial Relations:

1. whenever there is reason to believe that any AEC or AEC contractor employee or other individual (e.g., visitor, student not on payroll) on or off-site has, as the result of a single continuous exposure received over a short period of time any of the following:

(a) an external radiation exposure dose greater than 15 rem; or

(b) an internal body deposition greater than the maximum permissible concentrations of radioisotopes in the body as specified by AEC Manual Chapter Subsection 0524–02 e, *with the exception that for tritium the total exposure* shall be equivalent to 15 rem;

2. whenever there is reason to believe that any member of the general population off-site may have received as a result of AEC or AEC contractor activities a radiation exposure greater than those specified for external or internal exposure by AEC Manual Subsection 0524–02g; and

3. whenever it has been determined by the Manager of Operations or Headquarters Division Director that circumstances have occurred as a result of AEC or AEC contractor activities which are of AEC-public information significance.[5] [6]

b. An investigation is required if not accomplished under AEC Chapters 0502 or 0707, and an Investigation Report (see Appendix 0523–052b) submitted by the Managers of Operations to the appropriate Headquarters Operating Division Director with copies to the Divisions of Biology and Medicine, Finance, Inspection, and Office of Industrial Relations, within 30 days from the time of determination that any individual has received an estimated dose of 25 rems or more of external whole body penetrating radiation during the calendar year, or that any individual has received an immediately reportable radiation exposure as defined by Subsection 052a above.

---

[4] Refers to the total body and the internal organs.

[5] Public information significance as used herein means where members of the general public received information of an event resulting from AEC or AEC contractor activities which would be regarded as detrimental to the health and safety of humans, plants, animals, or property, such an event has AEC-public information significance.

[6] The release of public information concerning radiation exposures reported in accordance with Chapter 0523 is governed by AEC Manual Chapter 3105, Coordination of Oral, Written, and Visual Public Information Issuances.

0523-053 *Reports by Washington Designated Off-site Research Contractors.*—Washington designated off-site research contractors shall be required to submit the following to the extent determined reasonable[7] by the Manager of Operations:

a. annual radiation exposure information specified by Subsection 0523-051; and

b. special reports specified by Subsection 0523-052.

0523-06 *Retention and Disposition of Reports*

Radiation exposure reports prepared in accordance with the requirements of this Chapter shall be retained for those periods of time prescribed for AEC-direct activities by Appendix 0230-091, "AEC Records Schedule 11," and for AEC contractors' activities by AEC Appendix 0230-092, "AEC Records Schedule 8," and shall be disposed of in accordance with the provisions of AEC Manual Chapters 0230 and 0231. Special Reports submitted to the Director, Division of Biology and Medicine, Headquarters, shall be subject to the provisions of AEC Manual Chapters 0230 and 0231 in the same manner as are AEC-direct activities.

0523-07 *References*

The Atomic Energy Act of 1954, Chapter 4, Sections 31, 32; the Recommendations of the International Commission on Radiological Protection (ICRP); the Recommendations of the National Committee on Radiation Protection and Measurements (NCRP) as referenced in AEC Manual Chapter 0550, revised; and AEC Manual Chapter 0524.

Reporting Guide

This guide illustrates the summary report format and suggests an outline of contents for additional information and investigation reports to be submitted in accordance with AEC Chapter 0523. Where feasible, reports should be consistent with the examples.

It is requested that those data reported in tabular form be prepared on large-size paper similar to the worksheets used in accounting and that items be spaced generously. Investigation Reports may be divided into subject sections.

Summary of Whole Body Radiation Exposures
to
External Penetrating Radiation
Accumulated During the Year

Originating Office: Date Prepared:

Installation reported	Total Not Monit'd	No. of estim'd accumulated REM doses in each of following ranges								Total Monit'd
		0-1	1-2	2-3	. . . . .	12-13	13-14	14-15	>15	
Grand Totals										

REMARKS:

1. When letters are used for the first time to abbreviate the names of installations, show the full name here.
2. Additional information supplied on separate sheets in accordance with paragraph 0523-051 c. 4. should be attached to this report and listed here.

Checked by:

[7] "to the extent determined reasonable" means that, where a Washington designated off-site research contractor is able to justify his incapability to provide all of the information required without excessive cost or inconvenience, the Manager of Operations may determine what information provided by the contractor is sufficient to fulfill the reporting requirements of this Chapter.

Summary of Radiation Exposures Resulting In
the
Internal Body Deposition of Radioactive Material
For the Year

Originating Office: Prepared By:

Installation reported	No. of body depositions > 1/2 M. P. for isotope of interest									Total exposures >1/2 M.P.
	Pu	U238	U233	Po	Ra	H^3	F. P.	. . . .	Unknown	
Grand Totals										

REMARKS:
1. When letters are used for the first time to abbreviate the names of installations, show the full name here.
2. Additional information supplied on separate sheets in accordance with paragraph 0523-051. d. 5. should be attached to this report and listed here.
3. Insert a double entry for each isotope of interest -- one entry for the number of new (red ink) and one entry for the number of previously reported (black ink) body depositions being reported.

Checked by:

Report of Whole Body Dose Greater Than 15 Rem From External Penetrating Radiation Exposure

1. Date of Report
2. Personal Information
   a. Name (last, first, middle)
   b. Date of Birth
   c. Place of Birth
   d. Sex
   e. Social Security Number
3. Occupational Information
   a. Name and address of employer
   b. Position title of employee
   c. Area of facility employed in during period of exposure
4. Radiation Exposure Information
   a. Approximate dates for period during which exposure was accumulated
   b. Total estimated radiation dose in rem
   c. Type of radiation involved (e.g., x-ray, gamma, neutron, electrons, positrons, heavy particles)
   d. Manner in which personnel radiation dose measurements were made. (e.g., film badges, dosimeter, survey meter)
   e. Procedures used for converting units of measurement to REM dose values (e.g., survey meter reading in r times RBE of _____ for _____ radiation; _____ neutron tracks per square centimeter equals _____ rem dose; density of Dupont type 502 film in terms of r times RBE of _____ for _____ radiation)
   f. Extent to which the permissible accumulated radiation dose has been exceeded with respect to the provisions of AEC Manual Chapter Section 0524-02
   g. A copy of the Radiation Exposure Investigation Report required by subsection 0523-052 if completed and not previously submitted

Effective: October 10, 1958.
Revised: October 10, 1958.

REPORT OF RADIATION EXPOSURE RESULTING IN AN ESTIMATED INTERNAL BODY[1] DEPOSITION OF RADIOACTIVE MATERIAL GREATER THAN HALF THE MAXIMUM PERMISSIBLE LEVEL

1. Date of Report
2. Personal Information
   a. Name (last, first, middle)
   b. Date of Birth
   c. Place of Birth
   d. Sex
   e. Social Security Number
3. Occupational Information
   a. Name and address of employer
   b. Position title of employee
   c. Area of facility employed in during period of exposure
4. Radiation, Exposure Information
   a. Approximate dates for period during which exposure was accumulated
   b. Total estimated internal deposition of radioisotopes in microcuries of isotope of interest in appropriate organ (e.g., H^3 in total body, Ra^{226} in bone, Cs^{137} in muscle)
   c. Estimated fraction of the permissible amount of radioisotope deposited in the organ of interest
   d. Reference the biological assay procedure used in estimating the amount of deposition including the instrumentation (e.g., La-1858, fluorophotometer)
   e. Brief description of working conditions and other circumstances leading to exposure and probable mode of entry into the body (e.g., uranium machining operation hooded and ventilated, inhalation or ingestion suspected)
   f. Other pertinent bioassay and survey data and such interpretation of the data as the reporter has been able to make

INVESTIGATION REPORT OF RADIATION EXPOSURE

Where contractors have an incident investigation form that provides sufficient information, this should be used. In any event, each investigation report should include as much of the following information as can be obtained.

1. Date of report
2. Date or dates covering period in which exposure occurred
3. Name and address of contractor
4. Place where exposure occurred (i.e., name of installation, city, State, geographical area not within an incorporated area
5. Number of individuals (animals also if it is known or suspected that some have been exposed) believed to have been exposed to radioactive materials
6. Estimate of the total radiation exposure dose and radioisotope responsible for exposure
7. Media by which radioactive material was transported (e.g., gaseous effluent, airborne particles, aqueous effluent released to ground, airborne vapor)
8. Personal information regarding individuals exposed (e. g., name, home address, date of birth, place of birth, sex, social security number, employer's name and address, occupation at time of exposure)
9. Description of events leading up to and including the occurrence
10. Description of the role played by personnel, operating and emergency procedures, facilities, equipment, geographical location (topography)
11. Such interpretation as the reporting office may be able to make of the resulting conditions
12. Comments and suggestions that can be made to assist in the prevention of similar events
13. Description of survey instruments, monitoring procedures, analytical methods, standards for interpretation, and any other information concerning the manner in which radiation exposure was estimated and evaluated
14. Name and address of contractors' insurance company and whether or not the insurance company has been informed

[1] "Body" refers to all organs within the body and the whole body as an organ.

APPENDIX B–4

U.S. ATOMIC ENERGY COMMISSION—AEC MANUAL

TN–0000–238

TRANSMITTAL NOTICE

REVISION: CHAPTER 0502 INJURY, FIRE, AND PROPERTY DAMAGE—RECORDS, REPORTS, AND INVESTIGATIONS

1. Revision has been made to Chapter 0502 as follows:
   a. to "Responsibilities", Section 0502–03;
   b. in the definition of "Accidents and Fires" which are reportable under Subsection 0502–041;
   c. for requirement of additional notice to the Divisions of Inspection, Information Services and Biology and Medicine (Subsection 041);
   d. for requirement of investigations to comply with Sec. 170 of the Atomic Energy Act of 1954, as amended (Section 05).
   e. Appendix 0502–06 has been added.
2. FILING INSTRUCTIONS
   a. Please file this Chapter to replace the superseded one dated February 1, 1955.
   b. This Transmittal Notice may be filed for reference.

R. E. HOLLINGSWORTH
(For General Manager).

OCTOBER 16, 1958.

Volume: 0000 General Administration.

CHAPTER 0502 INJURY, FIRE, AND PROPERTY DAMAGE—RECORDS, REPORTS, AND INVESTIGATIONS

Revised: October 16, 1958

0502–01 *Purpose*

*This Chapter specifies the required reports, investigations, and records of accidents and fires. These data are used:
   a. to determine the cause of, responsibility for, and extent of injury, loss, or damage from accidents and fires;
   b. in the prevention of such occurrences and in the promotion of safety and fire protection and efficient operation; and
   c. to evaluate accident prevention performance.*

0502–02 *Scope*[1]

*This Chapter is applicable to direct AEC activities and to the following types of contract activities:
   a. construction and design;
   b. research and development;
   c. operation, maintenance, and service, of AEC facilities;
   d. supply contracts in which AEC has a substantial investment and other contracts determined by the appropriate Manager of Operations.*

0502–03 *Responsibilities*

*031 *Managers of Operations and Heads of Divisions and Offices, Headquarters,* are responsible for:
   a. assuring that all reported accidents and fires are promptly, thoroughly and adequately investigated by competent investigators;
   b. complying or assuring compliance with all the reporting requirements of this chapter;
   c. adopting or assuring the adoption of adequate preventive measures;
   d. assuring the preparation and release of public statements on fires and accidents in accordance with Chapter 3105, "Coordination Of Oral, Written And Visual Public Information Issuances";
   e. recommending whether an accident or fire should be reported to the JCAE; and
   f. reporting the probability of claims for payments under Chapter 14 Section 170 i of the Atomic Energy Act of 1954 as amended.*

[1] The requirements for reporting and investigating accidents and incidents involving licensees are covered in AEC Chapter 0707, "Investigation of Radiation Incidents Involving Licensed Activities", and 10 CFR Part 20, "Standards for Protection Against Radiation".

*032 *The Director, Office of Industrial Relations, Headquarters,* is responsible for:

a. reviewing reportable accident and fire reports for adequacy of recommendations and for value of information to other offices;

b. maintaining, consolidating, and summarizing accident reports for management; and

c. disseminating useful information about accidents and fires throughout AEC.*

033 *The Director, Division of Biology and Medicine, Headquarters,* is responsible for:

a. reviewing reported accidents involving exposure of personnel to radiation or chemicals for adequacy of recommendations and value of information to other offices; and

b. notifying Managers of Operations of the need for subsequent medical reports.

0502–04 *Immediate Reports.* The following shall be reported [2] immediately and investigated in accordance with Section 0502–05:

a. fatal or imminently fatal injury or illness of industrial origin of an employee or member of the public;

b. injury or industrial illness following cumulative or massive exposure to internal or external ionizing radiation which might reasonably be expected to have caused the illness or injury and when so diagnosed by a physician competent in nuclear medicine;

c. other injury or industrial illness of five or more persons in one accident or fire;

d. any accident involving radioactive materials when the responsible Manager believes it may have public relations significance or constitutes probable claims under Section 170 of the Atomic Energy Act of 1954 as amended;

e. estimated accidental loss or damage of $5,000 or more of Government property, including the value of source and special nuclear materials involved or estimated costs of $5,000 or more required for cleaning, renovating, replacing, or safely reusing building, equipment, or property contaminated with radioactive materials; [3] and

f. operational interruptions, other than scheduled shutdowns [4] or those caused by normal wear and tear, which cause a major building or area to be inoperable for a period significant to the particular type of operation.

The immediate report shall be transmitted by telephone or teletype. Report by telephone shall be confirmed by teletype on the same day, or as soon as sufficient information is obtained to indicate the nature and extent of the accident or fire. A copy of the teletype report shall be directed to the Headquarters Divisions of Inspection, Information Services, and the Office of Industrial Relations. If radiation or industrial toxicants are involved, the Director, Division of Biology and Medicine, shall also be notified, by telephone and a copy of the confirming teletype.*

*0502–05 *Investigations and Investigation Reports*

a. The investigation shall be made as soon as possible to determine causes; responsibility; extent of loss or damage, and whether there will be probable claims for payments under Section 170 i of the Atomic Energy Act as amended, and to recommend action for prevention of similar occurrences. A suggested outline for the report and criteria for determining loss is shown in Appendix 0502–043.

b. Within 30 days from date of accident, four copies of the investigation report shall be prepared. One copy shall be sent to the responsible Operating Division Director, one each to the Division of Inspection, the Office of Industrial Relations, and to the Division of Biology and Medicine if

---

[2] In reporting accidents involving radiation injury and radiation overexposures, cognizance shall be taken of Chapter 1405, "Insurance Claims Procedures," and 0521, "Medical Investigation of Alleged Disabilities From Special Hazards." See Chapter 0523–052 regarding reporting requirements involving radiation exposure.

[3] Where an accident, fire, or unusual operational incident results in loss or damage to source and special nuclear materials, the reporting requirements of this Chapter and Chapter 2601, "Administrative Handling of Violations and Related Matters," may be combined and identical reports submitted to all required recipients.

[4] Reactor shutdowns for removal of ruptured fuel elements or target material are not included unless other elements occur during the shutdown; e. g., investigations and reporting are required of exposure of personnel, or damage to the reactor in the process of removing the ruptured fuel elements or target material.

exposure of personnel to radiation or chemicals is involved. The report shall be accompanied by a statement as to relevant action which has been or will be taken.*

*0502–06 *Other Reports*

Appendix 0502–06 contains a list of other required reports and instructions as to scope, content, preparation, distribution and frequency.*

0502–07 *Availability of Records*

Copies of reports to be filed at Operations Offices, specified above, shall be retained in current files for one year following the year in which the accident or disability occurs.

0502–08 *References*

Bureau of Budget Circular A–5 (Revised), dated June 5, 1953; Civil Air Regulations; the Atomic Energy Act of 1954 as amended; Executive Order No. 7397, dated June 30, 1936; Executive Order No. 10194, dated December 19, 1950; AEC Manual Chapters 0210, 1521, 0552, 1405, and 2601.

REPORTS OF INVESTIGATIONS

The following outline is suggested for investigation reports; however, they should not be followed literally but rather the report should be organized in a manner that best reflects the facts disclosed.

1. *Summary of Basic Information*

Type, date and location of occurrence, name of injured, nature and extent of property damage, and estimate of loss.

*2. *Findings*

Events leading to the incident, factors contributing to severity of property damage, including major costs composing the loss. This should include all information and exhibits necessary to support the conclusions.*

3. *Conclusions*

Causes and responsibility, including comments on areas requiring research or engineering study to obtain adequate knowledge for hazard evaluation or control, as well as areas in which need for improved AEC safety guides or standards is indicated. State the probability of claims for payments pursuant to Section 170 i of the Atomic Energy Act of 1954 as amended.

*4. *Recommendations*

Recommendations should include all actions considered necessary for prevention and control of the severity of similar incidents.*

*5. *Signatures*

Committee members should be identified and should sign the report and any dissenting views reported.*

6. *Exhibits*

Include form report of incident, statements of witnesses and any photographs or sketches needed to clarify description of the incident.

PROPERTY EVALUATION AND CRITERIA FOR DETERMINING LOSS

Normal operational failure, e.g., due to premeditated overloading or wearing out of equipment, is not considered accidental property damage. Consequently, this shall not be reported as a "property damage accident." In determining the loss due to accidents and fires, the following shall be considered:

1. The estimated cost of replacement with identical units buildings, equipment, and materials, including source and special nuclear materials, which are lost, completely damaged, destroyed, or contaminated beyond further use. In the case of unused, obsolete, and excess buildings, equipment, and materials, the estimated market value at the time of the occurrence should be used.

2. The estimated cost of rehabilitating without improvement buildings and equipment which are contaminated or partially damaged.

3. The estimated cost of reprocessing and reclaiming partially destroyed and damaged materials.

4. The estimated salvage value of recoverable items.

5. The same factors used to determine the loss of Government property shall be used in arriving at the cost of private property involved in a fire or accident.

6. Burn out of electric motors and other electrical equipment through overheating from electrical causes will be considered fire only if self-sustaining combustion exists after power is shut off.

7. Damage from firefighting, such as water, smoke, and breakage damage, shall be included in the fire loss.

8. Expense incurred for clean-up of radioactive contamination caused by fire shall be included in the fire loss.

Property evaluation for fire and accident reporting purposes shall:

1. include the approximate replacement value of all AEC-owned buildings and equipment; the replacement value shall be calculated by applying to the original cost (or most recent appraised value) an appropriate cost index ratio (Cost index data published by Smith, Hinchman & Grylls, Inc.) shall be used;

2. include cost of all Government-owned supplies;

3. include the average inventory of all source and special nuclear materials;

4. exclude land and land improvements such as sidewalks, roads, etc.; and

5. exclude below-ground facilities not susceptible to damage by fire or explosion, such as major water mains, water ponds, etc., which are carried as separate capital accounts.

List of required reports and instructions

Form No. and title	To be used in reporting—	To be prepared by—	Report distribution	Comments
Standard Form 91, "Operators Report of Motor Vehicle Accident."	Accidents involving a Government-owned or leased motor vehicle resulting in personal injury and/or property damage, regardless of whether or not vehicle was in motion at time of accident.	AEC operator	To AEC office having custody of motor vehicles.	If possible, forms should be completed at scene of accident.
Form AEC-271,[1] "Motor Vehicle Accident Report."		Contractor operator	To contractor office having custody of motor vehicles.	See ch. 0553-05 for definition of "motor vehicle." If two or more vehicles of same reporting unit involved, report as single accident. Where different reporting units are involved, each unit should report but include only damage to its own vehicle and property.
Standard Form 91A,[1] "Investigation Report Motor Vehicle Accident."	Results of investigation of each motor vehicle accident causing property damage of $50 to $5,000 including damage to private property, where motor vehicle involved was in motion (i.e., not properly parked) at time of accident.	AEC or contractor official with assigned responsibility for investigating motor vehicle accidents.	Original to Operations Office; copy to Office of Industrial Relations, attention: Safety and Fire Protection Branch.	
Standard Form 92,[1] "Supervisor's Report of Accident."	(1) Accidental property damage of $50 to $5,000 other than damage resulting from an aircraft accident or from an accident involving a motor vehicle in motion, including damage to a motor vehicle which was properly parked at time of accident. (2) Accidents or occurrences resulting in personal injury other than injury from motor vehicle accidents.	AEC or contractor supervisor.	Original to Operations Office; copy to Office of Industrial Relations, Headquarters, attention: Safety and Fire Protection Branch.	See American Standard Method Recording and Measuring Work Injury Experience, Z16. Doubtful cases of occupational injury should be reported for interpretation by American Standards Association.
Form AEC-283,[1] "Report of Fire or Similar Accident."	(1) Loss of $50 to $5,000 of Government property resulting from fire, explosion, lightning, windstorm, flood or sprinkler leakage, and any loss or damage of private property. (2) Each municipal loss from above causes where total damage (Government plus private) is estimated from $500 to $5,000.	AEC office or contractor having custody of property damaged.	Original and at least 1 copy to Operations Office; copy to headquarters accompanying form AEC 13A-13B.	See app. 0502-09 for information on property evaluation and determining loss. See ch. 0551 for definition of "municipal."
CAA-2400, "Pilot/Operator Aircraft Accident Report" and such other reports as required by Civil Aeronautics Administration.	Each aircraft accident	Pilot/operator and such other AEC or contractor offices as required by CAA regulations.	As required by CAA Regulations. 1 copy CAA-2400 and other related reports to be sent to Office of Industrial Relations, attention: Safety and Fire Protection Branch.	See Civil Air Regulations, pt. 62.

[1] Approval of Safety and Fire Protection Branch, Headquarters is required for substitute forms used by contractors for reporting accidents and fires.

List of required reports and instructions—Continued

Form No. and title	To be used in reporting—	To be prepared by—	Report distribution	Comments
Form AEC 13, Monthly Summary—Accident, Occupational Disease and Fire Experience.	Monthly summary of all accidents, occupational diseases, fires and other property damage or loss from other causes resulting from personal injury or damage or loss of property in excess of $50. Include in the report for the month in which discovered previously unreported accidents, injuries, and fires of the current calendar year.	Contractor; other than research contractor with annual budget below $200,000.	To Operations Office	Where a monthly report includes data on an accident, injury, or fire occurring in a previous month of the current year, it will be necessary to make appropriate adjustments in disability time charges and damages in the report.
Form AEC 13A, Monthly Tabulation of AEC and Contractor Lost Time Occupational Injury Experience.	Monthly tabulation of all lost time, occupational injury experience of AEC Operations Office or reported by contractors on AEC Form 13.	Operations Office	To Office of Industrial Relations, attention: Safety and Fire Protection Branch, through channels not later than the 17th of the month succeeding the report month.	To the extent applicable, the comments on form AEC 13 govern the preparation of form AEC 13A.
Form AEC 13 B, "Quarterly Tabulation of Fire, Motor Vehicle Accident and other Property Damage Experience."	Quarterly tabulation of property damage or loss to Operations Offices (in excess of $50 per incident) resulting from fires, motor vehicle accidents, aircraft and other property damage accidents as reported to Operations Offices by contractors on form AEC 13.	Operations Office	To Office of Industrial Relations, attention: Safety and Fire Protection Branch, through channels not later than the 17th day of April, July, October, and January.	Basis is form AEC 13; accident involving 2 or more Government owned or leased motor vehicles (contractor or AEC operated) should be reported as a single accident.
Annual Summary of Fire Program and Experience.	(As described in ch. 0551–06)	Managers of Operations	To Office of Industrial Relations, attention: Safety and Fire Protection Branch, through channels not later than February of each year.	See ch. 0551–06.
Quarterly Activity Report (in narrative form).	AEC and contractor safety and fire protection activities including review of such items as: (1) personnel and program changes; (2) major projects started or completed; (3) surveys initiated, in process or completed; (4) unusual problems encountered; and (5) new ideas, equipment and procedures.	Managers of Operations	To Office of Industrial Relations, attention: Safety and Fire Protection Branch, through channels not later than the 17th day of April, July, October, and January.	

APPENDIX C–1

Byproduct, source, and special nuclear material licensees by State as of Nov. 30, 1958

State	Byproduct material							Source material	Special nuclear material	Total material licensees
	Medical institutions and physicians	Colleges and universities	Industrial	Federal and State laboratories	Foundations and institutions	Other	Byproduct total			
Alaska	3	1	0	4	0	0	8	0	0	8
Alabama	33	4	24	13	0	0	74	6	0	80
Arizona	6	3	4	0	0	0	13	16	0	29
Arkansas	21	1	7	4	0	0	33	5	1	39
California	197	10	173	33	3	6	422	243	36	701
Colorado	27	5	14	13	0	4	63	159	2	224
Connecticut	20	5	36	16	4	1	82	29	6	117
Delaware	3	1	11	3	0	0	18	25	2	45
District of Columbia	23	3	3	27	0	1	57	9	10	76
Florida	49	6	12	8	0	2	77	2	1	80
Georgia	27	4	14	7	0	0	52	10	2	64
Hawaii	11	1	2	25	2	0	41	0	0	41
Idaho	4	2	2	0	0	0	8	11	0	19
Illinois	105	18	100	28	5	3	260	53	7	320
Indiana	41	6	40	5	0	1	93	10	4	107
Iowa	26	5	9	20	0	1	61	1	2	64
Kansas	24	2	10	5	0	0	41	10	1	52
Kentucky	18	3	12	2	0	2	37	2	0	39
Louisiana	27	3	26	4	0	3	63	3	1	67
Maine	5	2	14	5	1	1	28	2	0	30
Maryland	22	4	21	18	0	1	66	13	7	86
Massachusetts	51	27	81	14	6	2	181	60	17	258
Michigan	79	8	45	30	3	2	167	37	12	216
Minnesota	36	6	18	76	0	1	137	8	4	149
Mississippi	8	3	4	1	0	0	16	0	1	17
Missouri	56	8	21	11	1	4	101	22	13	136
Montana	9	2	2	2	0	0	15	5	0	20
Nebraska	16	1	2	3	0	1	23	0	0	23
Nevada	4	1	1	2	0	0	8	13	1	22
New Hampshire	5	3	4	5	1	0	18	1	0	19
New Jersey	66	4	112	8	2	2	194	38	4	236
New Mexico	13	3	6	4	0	0	26	39	1	66
New York	271	22	160	58	4	8	523	120	26	669
North Carolina	39	6	12	9	0	1	67	6	3	76
North Dakota	9	2	0	1	0	0	12	3	0	15
Ohio	101	11	71	16	4	2	205	63	12	280
Oklahoma	25	2	31	5	2	1	66	10	3	79
Oregon	18	3	6	5	0	0	32	10	2	44
Pennsylvania	95	16	137	44	2	0	294	62	25	381
Puerto Rico	9	2	0	3	0	0	14	0	1	15
Rhode Island	8	2	12	3	0	0	25	2	0	27
South Carolina	9	2	4	1	0	0	16	2	1	19
South Dakota	11	1	0	9	0	0	21	29	1	51
Tennessee	37	7	20	7	0	2	73	8	4	85
Texas	128	8	90	25	4	3	258	31	13	302
Utah	9	4	4	5	0	1	23	151	2	176
Vermont	2	1	2	1	0	0	6	0	0	6
Virginia	34	7	24	12	0	3	80	8	5	93
Washington	24	4	16	10	0	1	55	15	4	74
West Virginia	21	1	10	4	0	0	36	7	1	44
Wisconsin	52	3	32	4	5	1	97	8	3	108
Wyoming	7	1	2	3	0	0	13	91	0	104
Total	1,945	260	1,463	621	49	62	4,399	1,458	241	6,098

APPENDIX C–2

FACILITY LICENSES

CONSTRUCTION PERMITS IN EFFECT AS OF NOVEMBER 30, 1958

Power Reactors:

Consolidated Edison Co., Indian Point, N. Y.
Commonwealth Edison Co., Grundy County, Ill.
Power Reactor Development Co., Loagoona Beach, Mich.
Yankee Atomic Electric Co., Rowe, Mass.
Total, 4.

Test Reactors:
Westinghouse Electric Corp. (WTR), Waltz Mill, Pa.
General Electric Co. (GETR), Alameda County, Calif.
National Aeronautics and Space Administration, Sandusky, Ohio
Total, 3.
Research Reactors:
Aerojet-General Nucleonics (CPRR–13—6 AGN–201 reactors #115 through #120), San Ramon, Calif.
Ordnance Materials Research Office, Watertown, Mass.
Union Carbide Corp., Sterling Forest, N. Y.
University of Florida, Gainesville, Fla.
University of Virginia, Charlottesville, Va.
Aerojet-General Nucleonics (CPRR–24—15 AGN–201 reactors #126 through 140)
Aerojet-General Nucleonics (CPRR–23—5 AGN–201P reactors #121 through 126)
Aerojet-General Nucleonics (CPRR–27—8 AGN–211 reactors #102 through 110)
University of Arizona (TRIGA), Tucson, Ariz.
Cornell University, Ithaca, N. Y.
North Carolina State College (Pool-Type), Raleigh, N. C.
Total, 11 (for the construction of 41 reactors, 34 AGN).
Critical Experiment Facilities:
Allis-Chalmers Manufacturing Co., Greendale, Wis.
National Aeronautics and Space Administration, Cleveland, Ohio
Total, 2.
Total Construction Permits, 20.

LICENSES IN EFFECT AS OF NOVEMBER 30, 1958

Research Reactors:
Pennsylvania State University, University Park, Pa.
North Carolina State College, Raleigh, N.C.
Armour Research Foundation, Chicago, Ill.
Battelle Memorial Institute, West Jefferson, Ohio
Naval Research Laboratory, Washington, D.C.
Aerojet-General Nucleonics (AGN–201M, Ser. 103), San Ramon, Calif.
Aerojet-General Nucleonics (AGN–201, Ser. 108), San Ramon
University of Michigan, Ann Arbor, Mich.
Curtiss-Wright Corp., Quehanna, Pa.
General Dynamics Corp. (TRIGA), San Diego, Calif.
Massachusetts Institute of Technology, Cambridge, Mass.
Aerojet-General Nucleonics (AGN–201, Ser. 110)—Scheduled for export to Italy
North American Aviation, Inc. (Model L–77), Canoga Park, Calif.
American Radiator & Standard Sanitary Corp. (UTR–1), Mountain View, Calif.
Aerojet-General Nucleonics (AGN–211, Ser. 101), San Ramon, Calif.
The Babcock & Wilcox Co. (Pool-Test), Lynchburgh, Va.
Industrial Reactor Laboratories, Inc., Plainsboro Township, N.J.
Nuclear Development Corp. of America, Pawling, N.Y.
Aerojet-General Nucleonics (AGN–211, Ser. 102), San Ramon, Calif.
Total, 19 reactors.
Power Reactors: General Electric Co. (VBWR), Alameda County, Calif.
Total, 1.
Test Reactors: None.
Research Reactors:
U.S. Naval Postgraduate School, Monterey, Calif. (AGN–201, #100)
Oklahoma State University of Agriculture & Applied Science, Stillwater, Okla. (AGN–201, #102)
Texas A. & M. College, College Station, Tex. (AGN–201, #106)
University of Akron, Akron, Ohio (AGN–201, #104)
University of Utah, Salt Lake City, Utah (AGN–201, #107)
Colorado State University, Fort Collins, Colo. (AGN–201, #102)
U.S. Naval Hospital, Bethesda, Md. (AGN–201M, #105)
University of California, Berkeley, Calif. (AGN–201, #112)
Catholic University, Washington, D.C. (AGN–201, #101)
University of Delaware, Newark, Del. (AGN–201, #113)
Oregon State College, Corvallis, Wash. (AGN–201, #114)
Total, 11.

Critical Experiment Facilities:
The Babcock & Wilcox Co., Lynchburg, Va. (Con-Ed)
The Babcock & Wilcox Co., Lynchburg, Va. (NMSR)
The Babcock & Wilcox Co., Lynchburg, Va. (LMFRE)
Battelle Memorial Institute, West Jefferson, Ohio (possess only)
Nuclear Development Corp. of American, Pawling, N.Y. (possess only)
General Dynamics Corp., Torrey Pines Mesa, San Diego, Calif.
General Electric Co., Alameda County, Calif. (Commonwealth)
The Martin Co. (MPR & ERDL), Middle River, Md.
Westinghouse Electric Corp. (Yankee & Br–3), Waltz Mill, Pa.
Westinghouse Electric Corp. (WTR criticals), Waltz Mill, Pa.
Total, 10.
Total Facility Licenses, 41.

APPENDIX C–3

Radioactive isotope distribution data [1]

Radioactive isotopes	Aug. 2, 1946–Dec. 31, 1957		Jan. 1, 1958–Nov. 30, 1958		Total to Nov. 30, 1958	
	Activity (Curies)	Shipments	Activity (Curies)	Shipments	Activity (Curies)	Shipments
Iodine ^{131}	4,866	37,596	1,008	3,432	5,873	41,028
Phosphorus ^{32}	1,262	21,955	215	2,183	1,476	24,138
Carbon ^{14}	59	2,910	9	237	68	3,147
Tritium	12,228	597	37,289	165	49,516	762
Strontium ^{89}, ^{90}	438	1,252	53	150	490	1,402
Cobalt ^{60}	336,513	1,681	170,939	189	507,452	1,870
Cesium ^{137}	11,348	922	5,491	147	16,839	1,069
Iridium ^{192}	16,672	462	5,031	140	21,723	602
Others	2,462	22,457	2,769	5,219	5,234	27,676
Irradiated units [2]	----------	14,692	----------	1,208	----------	15,900
Total [3]	385,848	104,524	222,823	13,070	608,672	117,594

[1] Shipments from Oak Ridge National Laboratory.
[2] Includes irradiated units of iodine ^{131} and phosphorus ^{32}.
[3] Increased acceleration in use of tritium and cobalt ^{60} caused principal growth in curies shipped in 1958.

APPENDIX D–1

RADIATION EXPOSURE AND COMPENSATION

By James H. Sterner, M.D., Medical Director, Eastman Kodak Co., Rochester, N.Y., December 12, 1958

The problems involved in the determination of compensation awards for radiation injury reflect the complexity and uncertainties of the whole problem of the biological effects of ionizing radiation. The superimposing of economic, sociologic, medicolegal, and emotional considerations inherently associated with our mechanisms for awarding compensation, in view of the highly technical and complicated nature of radiation exposure and radiation injury, are likely to result in confused, inequitable, and scientifically unsound judgments. The remote and delayed effects of radiation injury, such as carcinogenesis, shortening of life span, and genetic implications, while not novel to the problem of compensable injury, impose a new potential because of the experimental studies focusing attention on these effects, and because of the considerably greater number of people involved occupationally with the hazardous agent. In addition, the frequent references to the fact that "all radiation is harmful," and the confusion as to whether, at the lower levels of exposure, radiation injury has a "linear" or a "threshold" relationship to the exposure, imply that the problems associated with ionizing radiation are qualitatively different from those of other common industrial hazardous physical and chemical agents.

In this discussion, the emphasis will be on the relationships among radiation exposure, radiation injury, and compensability in the area of occupational injury and disease compensation. It is likely that the greatest number of problems, and their earlier appearance, will occur here because of the significant number of people exposed to radiation in their occupation.

The relationship between the quantitative and qualitative factors of exposure and injury have been defined for many industrial physical and chemical agents. The concept of a "maximum allowable (or permissible) concentration," or a "threshold limit" for a considerable number of industrial toxins is widely accepted as one of the most important elements in preventing occupational disease. A table of threshold limits, now including values for more than 200 industrial physical and chemical agents, is reviewed annually and approved by the American Conference of Governmental Industrial Hygienists (A.C.G.I.H.). The members of this organization are from Federal, State, and city health and labor agencies responsible for protecting the health of employed people. The threshold limits define exposure conditions which have been established by clinical and experimental studies as "safe" for continuous exposure during the working lifetime. There is general agreement, that in the application of these limits, it is desirable to maintain the exposure at the lowest practical values, but that if these limits are not exceeded, no significant injury is likely to occur.

The "threshold limits"—or "maximum permissible exposure" (m.p.e.) values for ionizing radiation have been developed by the National Committee on Radiation Protection and Measurement (N.C.R.P.M.). This organization early accepted the responsibility for such criteria, and their recommendations have been adopted by the A.C.G.I.H., as valid and authoritative. A number of the States have recognized the values established by the N.C.R.P.M. in industrial codes defining safe working conditions, and it is likely that all States with significant occupational radiation exposures will eventually do so.

In the adjudication of a claim for alleged occupational injury involving an exposure to an industrial toxin not greater than the well established threshold limit, the testimony from recognized, competent medical experts as to the absence of injurious effects at or below the threshold limit is likely to carry considerable weight in the final judgment. However, not infrequently testimony supporting such a claim may come from a physician without special knowledge and experience in toxicology, nor with the particular toxin in question. In such instances the jurist, or referee, or board must evaluate not only the technically difficult testimony, but the qualifications and competence of the physicians testifying. Finally, he (or they) must establish a "probability factor," defining the place of the incident in the range of likelihood which extends from "possible" to "probable." With an admitted and proper philosophy which gives the "benefit of the doubt" to the injured workmen, decisions by Workmen's Compensation authorities have sometimes extended, by medicolegal action, the range of "cause and effect" relationships far beyond that which is medically sound and reasonable. It is likely that the problems associated with the evaluation of radiation exposure and radiation injury will present even greater difficulties.

Let us consider some of the circumstances which claims for compensation may arise. In the first instance, let us assume that an individual whose carefully and well measured and documented work exposure to ionizing radiation is at or below the maximum permissible exposure level. The N.C.R.P.M., in describing the application of these limiting values urges that radiation exposure be reduced to the lowest practical level. This recommendation is consistent with that given by the A.C.G.I.H. and other responsible advisers on industrial health for all exposures to hazardous physical and chemical agents. However, with the common industrial toxins, it is generally accepted that a threshold exists, and that the "factor of safety" which is applied in developing the "threshold limit" precludes injury, or at least serious injury, if the exposure is controlled at or below the permissible level. With radiation exposure, however, a somewhat different concept has developed. The still unsolved problem as to what biological effects observe a "linear" or a "threshold" relationship to radiation, particularly with the potential extending to future generations, has signalled caution, even at lower exposure levels. The frequency and prominence of the repetition that "all radiation is harmful" implies a significant quantitative importance. In one sense, the radiation problem has been complicated by the tremendous amount of research reported, for such factors as shortening of life span and likelihood of producing mutations have not been investigated thoroughly for any other industrial physical or chemical agent. In addition, the concern expressed with the fallout problems, involving the whole population, becomes confused with the consideration of the occupational exposure.

In determining the effect of an occupational hazardous agent, the final, and most significant measure is in the complete medical evaluation of the exposed individuals. Prior to the Manhattan Project, the population occupationally exposed to low levels of radiation at or below recent "m.p.e." values was too

small and not sufficiently controlled to provide valid information as to possible injurious effects. With the advent of the Atomic Energy program, and the establishment of good industrial medical services in the various plants and laboratories, observations of greater value have been made. It is now more than 16 years since the first successful operation of a nuclear reactor, and some 15 since the plants in Oak Ridge, Los Alamos, and Hanford expanded to involve occupationally thousands of people in radiation exposure.

During the earliest phase of operation, the "m.p.e." of 100 mr per day was sometimes interpreted as meaning 500 mr per week or 25 r per year. Later this was reduced to 300 mr per week, or 15 r per year, a permissible level which has only recently been lowered to 5 r per year. An analysis of the external radiation exposure among some 200,000 atomic energy industry contractor personnel for the 9 years, 1947–1955, inclusive, showed that more than 99.4 percent of the workers received less than 5 rem of external radiation, and only 0.01 percent received more than the "m.p.e." of 15 rem per year. This is exclusive of the limited number of accidents, which are reported separately. The highest individual dose, averaged over the 9-year period, was 16.4 rem, only slightly greater than the permissible level. The highest dose for any 1 year is 27.8 rem. When the 10 highest exposures in any 1 year are averaged, the value is only slightly greater than 5 rem. Over the 9-year period, the average for the 10 highest exposures was 3.4 rem.

During the war years, with the urgency of production, and the difficulties in providing and enforcing protective measures, exposures in many instances were somewhat greater than encountered in operations since 1945. A number of these exposed individuals have remained in work in the atomic energy industry to the present, so that we now have some 15 or 16 years of observation. A program of thorough, periodic examinations, such as are done in the chemical industry to assess the occupational hazards, has not revealed a single evidence of significant injury under the above conditions of exposure. Admittedly, in considering the delayed effects of radiation, a 15-year observation is too short a period for a final evaluation.

The term "significant" injury was used above to exclude the reported findings of slight but "statistically significant" shifts in the total white blood cell counts, the neutrophilic leukocyte counts, the lymphocyte counts, the increased incidence of bilobed and binucleated lymphocytes, the increase in refractile neutral red bodies in lymphocytes, or the increased lymphocytic content of desoxyribonucleic acid. The slight shifts in white cell counts, within the variable normal limits, cannot be related, with our present knowledge, to the serious depressions of the hematopoiectic system which occur with high radiation exposure. Similarly, the finding of an increased incidence of bilobed lymphocytes or of certain staining qualities of the lymphocytes, even though associated with radiation exposure, among other conditions of stress, does not, with present information, indicate "radiation injury."

I believe that no thorough and comprehensive study has been made thus far among the long-term atomic energy industry employees of such factors as the incidence of cancer, length of life, and genetic changes. A number of physicians, cognizant of these potential hazards and associated with these industrial medical programs for 10 or more years, have not thus far observed any significant abnormal finding which was associated with these lower levels of exposure. If we apply to the "m.p.e." levels for radiation the same criteria for judging the effectiveness in preventing injury as we do to other industrial hazardous chemical and physical agents, we must conclude, from our experience thus far, that the values are prudent, critical, and effective. We want to emphasize again that we have much more information, from clinical and experimental sources, concerning the effects of radiation than we do for any other hazardous industrial agent.

In considering the delayed, and more difficultly determined effects of radiation such as carcinogenesis, and shortening of life span, the direct evidence indicating a relationship in man at or below the "m.p.e." is completely lacking. The information developed from a study of the life span of radiologists as judged from the age at death, initially was interpreted to mean that radiation exposure was a predisposing factor in the shortening of life. The radiation exposure for these radiologists was certainly much greater than the "m.p.e." levels discussed above. Subsequently it was shown that the initial interpretation in this study failed to take into consideration a significant difference in the average of the radiologists, and it was concluded that the differences in ages at death could have occurred by chance alone. A widely quoted estimate of life shortening in man was 15 days per roentgen; in a later analysis, using substantially the

same data, a value of 1 day per roentgen was obtained. Such calculations are justified in the absence of reliable direct data, but have little or no usefulness in the evaluation of a specific case.

While the evidence from animal studies, of a "linear" relationship between radiation dose at low levels and genetic effects is more convincing than for somatic injury, its potential role in compensation matters must be entirely speculative at this time.

When an individual receives a massive dose of radiation, the objective signs of injury become increasingly evident as the dose exceeds 100 rads. Subjective symptoms such as nausea, vomiting, apprehension, weakness, and fatigue are difficult to evaluate, and may be influenced by what the patient is told or has learned, or by the reflected concern of medical, safety, and administrative personnel. Such signs as epilation, fever, depression of hematopoietic factors, cutaneous burns are related in severity to the magnitude of the exposure. The problem of determining compensation during the period of acute disability is not difficult. In the case of severe superficial burns, the frequently prolonged course, and even the delayed hyperkeratoses, areas of thin atrophic sensitive skin, or subsequent malignant degeneration find precedence with related occupational conditions, and reasonably direct evaluation. The conditions of such severity as to cause obvious and continuing disability present little difficulty in compensation determination. When the patient has recovered sufficiently to return to work, the matter of evaluating "residual" injury may become extremely difficult. The strictly medical determination will necessarily involve such considerations as shortening of life span and increased likelihood of malignancy—leukemia, cancer, sarcoma. Should a payment for permanent partial disability, or a lump-sum settlement include a consideration for such events? Or should payment be made only for the measurable disability, and subsequently amended only if the neoplasm develops?

The question of compensation will arise certainly in the case of an individual who has received substantially more radiation than the "m.p.e.", but not in a large enough acute exposure to develop the signs and symptoms of radiation sickness. Particularly, with disease conditions the specific causes of which are not clearly identified, it has been a common experience that the person exposed to a hazardous material reasons, "I did not have this condition before I was exposed; therefore, the illness must be a result of the exposure." This "post hoc-propter hoc" reasoning frequently extends to the physician treating the case, and apparently to the Workmen's Compensation authorities. The very nature of our mechanism for determining compensation awards encourages the physician, testifying for the plaintiff or the defendant, to become an advocate for his side. The confusion, and subtle distinction between what is "possible" and the various degrees of "probability" are likely to become greatly magnified in considering radiation exposure and radiation injury.

To achieve a fair and equitable determination of compensation in instances of radiation injury, a tremendous amount of additional information is needed. The extrapolation from experimental work on lower animal species, and from exposure conditions which vary significantly from those actually incurred in work conditions allow too large a margin of error. Additionally, we need a mechanism for digesting, interpreting, and evaluating the almost overwhelming amount of information relating exposure to injury. The N.C.R.P.M. makes an important contribution in establishing guides for controlling the industrial environment. For the physician who must testify in a particular claim for compensation, for the judge or referee who must weigh and decide the evidence, additional and much more specific guidance is needed. A wide divergence of opinion on many aspects of radiation injury exists and will continue to exist among the people with special knowledge in this area. These opinions appear in the scientific literature, but with varying degrees of substantiation and intent, so that an individual with limited knowledge in this area, seeking guidance, will find it extremely difficult to obtain a balanced, critical, objective crystallization of the current concepts.

Guides for the evaluation of disability for other types of injury have been developed, and have played an important part in establishing a stable, fair, and sound adjudication of occupational injury and disease claims. Such a guide relating radiation exposure and radiation injury, reflecting the considered judgment of the professional organizations with special knowledge in this area, would seem to be a more reasonable criterion than the composite, frequently widely divergent, conclusions developed from a succession of compensation hearings. Many objective authorities are reluctant to attempt such a guide, with our present limited knowledge. They must be impressed with the fact that judgments must be made, and are being made by people with much less competence, information, and objectivity.

APPENDIX D–2

RADIATION AND COMPENSATION

(By Shields Warren, M.D. scientific director, Cancer Research Institute, New England Deaconess Hospital, Boston, Mass.)

The question of compensation for radiation injury is unusually complex because the basic mechanisms by which radiation induces injury are not clearly understood. Injury may be produced by very small but often repeated doses of radiation. Even after acute and obvious radiation injury there may be long-delayed chronic effects. One of the oldest known industrial diseases, the lung sickness of the miners at Joachimsthal and Schneeberg, from the ore of which Mme. Curie isolated radium decades ago, had long been associated with some peculiar property of these mines. This illness is now known to be cancer of the lung, due in all probability to the high radon content of the air in the mines and the long, though slight, exposure of the tissues to radon and its products. Seventeen to twenty years of exposure is required to cause lung cancer, and only a fraction of those exposed to this radiation develop the disease.

While we know more about radiation and its effects on living cells than we know about many injurious agents, there are still large areas of uncertainty. The human race has been exposed to small amounts of naturally occurring background radiation since the race began but it is only a little over 60 years ago that artificial sources of ionizing irradiation were discovered and only within the last two decades that large numbers of people became potentially exposed to them. Our sources of knowledge of radiation injury are derived in large part from studies of the following:

(1) Patients who have been exposed to X-rays or radium for diagnosis or treatment.
(2) Radiologists and their technical assistants.
(3) Patients treated with radioactive isotopes.
(4) The atomic bombed populations of Hiroshima and Nagasaki.
(5) The Marshallese and the Japanese fishermen exposed to heavy fallout radiation.
(6) The victims of the relatively few accidents in the atomic energy programs of different countries.
(7) Experimental data obtained from irradiation of plants and animals.

Additional information may prove to be obtainable from studies of populations living in regions of high natural radiation background as contrasted with those in low.

The problem of industrial compensation is complicated because it involves economic, emotional, and personal factors that serve to obscure further a field that is inherently difficult to evaluate. One must recognize, therefore, that in the attempt to apply incomplete scientific knowledge to problems of compensation our present system may well involve uncertainties as well as some inequities. In reading the following discussion it should be kept in mind that the benefit of the doubt in case of uncertainty should be given to the worker.

We may divide radiation injury into three great classes:

(1) Obvious and fairly prompt damage to the exposed individual, often followed by some degree of delayed injury;
(2) Delayed damage to the exposed individual;
(3) Damage to offspring of the exposed individual.

The concept of a permissible level of radiation rests on a general assumption. This is that we cannot in practical daily life avoid all risks but must endeavor to regulate our activities in such a way that the risk from any given source is not unacceptably great. The degree of acceptability varies. For example, we accept tens of thousands of deaths caused by automobiles as balanced by the convenience and speed of transportation. On the other hand, two or three deaths from smallpox would be regarded as a great threat and would lead to emergency measures for control. Every traveling salesman expects to gain from the travel inherent in his work. On the other hand, he clearly places himself at increased risks when he undertakes this travel.

The risk from radiation under present practices is startlingly low. Three workers have died as a result of radiation injury in the operations of the Manhattan District and the Atomic Energy Commission. Less than 50 have suffered detectable injury. This is among many thousands at risk and indicates that the atomic energy industry as now operated is not hazardous.

Still another aspect of the atomic industry is the knowledge that a very large-scale atomic accident, while extremely unlikely to happen, could, nevertheless,

be catastrophic in its effects. Consequently, the relative safety of the industry for the individual has become to some extent overshadowed by the great potential risk inherent in an accident that has not occurred, in all probability will not occur but can conceivably occur.

The fact that exposure to radiation may have long-delayed effects renders the question of determining compensation exceedingly complex. When a man has a leg broken in a plant he knows of the injury at once; he knows about how long he will be disabled; he knows that in the great majority of instances he will be able to go back to work. In radiation injury, on the other hand, there may be no immediate perceptible sensation or alteration in the body or, if there is, this may be followed by a very considerable period of apparent health and well-being before further evidence of injury appears. Definite evidence of injury may not appear for 15 or 20 years after the exposure. This, then, makes the compensation of radiation injury a very difficult problem. One might need to exclude such late effects from the operation of the statute of limitations or to establish a scale of compensation for putative future damage based on the probable future effects of the type and amount of excessive radiation received.

There are two conflicting theories as to the amount of radiation required to produce injury, whether immediate or delayed. The first, based on genetic observations on a number of forms of living plants and animals, assumes that injury is cumulative, independent of radiation rate, and that the probability of damage increases directly as does the total dose received, whether it be received at one time or at many different times. This is called the linear hypothesis. In contrast to this is the experience gained from observations on plants, animals and man that so far as a given individual is concerned, small amounts of radiation have no observable effect due to the reparative functions of the body and only when radiation exceeds a certain, though as yet unknown, point does injury appear. This is the so-called threshold theory. The truth probably lies somewhat between these points.

PROBABILITY OF INJURY RESULTING FROM MASSIVE DOSES OF RADIATION

Massive doses of radiation may be assumed to be radiation of the entire or virtually entire body received in a short time (seconds to hours) and totaling 200 rad or more. At about 200 rad absorbed within a period of minutes, death of a few susceptible persons can result. In all probability, however, less than 10 percent of any exposed group would die at about 200 rad. With a dose of 400 to 450 rad about half of the exposed individuals would die and the survivors would have some degree of illness lasting from days to months but would recover almost entirely later; an unknown but small percentage would develop diseases of the blood such as leukemia and possibly show slight evidence of premature aging resulting in a lifespan shortening of 2 years or less. From the genetic standpoint men or women so exposed would probably show transient sterility of 2 to 4 years' duration. On recovery of fertility, they would have a slight but unknown increase in likelihood of congenital malformations in their offspring.

Those receiving 800 rad or above would almost certainly die.

The same dose of radiation received in protracted fashion has much less effect on the body than when received acutely. Many radiologists have received about 15 rad per year of protracted radiation for many years without demonstrable ill effect. There is some evidence that at a total protracted dose of about 1,000 r life may be shortened several years and leukemia be more prevalent.

Much higher doses of radiation are tolerated by portions of the body than by the whole body. Thus 400 r of acute whole body radiation may kill; 5,000 r of acute or slightly protracted radiation appled to a small area of the skin may cure a skin cancer and produce only a scar.

The effects of inhalation, swallowing, or introduction through the skin of radioactive materials such as radium, plutonium, or strontium 90 will not be considered in detail here. There are many data on the danger from these substances in animals, a small amount of data in man. Permissible occupational limits have been set for these and other radioactive substances by the National Committee on Radiation Protection based largely on animal experiments and studies of the victims of radium dial painting and of some persons who received supposedly therapeutic doses of radium-containing water in years past. The chief effects to be expected from overdosage of radium is localized, low-grade inflammatory change in bone followed in many years by bone tumor. If inhaled, there would be increased danger of lung cancer. Severe anemia would also be a possibility. Only one case of leukemia has followed radium poisoning.

No injury has as yet been demonstrated in man from either plutonium or strontium 90. However, data in animals indicate that plutonium is an effective

carcinogenic agent and that strontium 90 is an effective agent in the production of bone sarcoma and may be a leukemogenic agent.

Different types of radiation produce effects different in degree but not in kind. Observations have made possible the establishment of factors permitting comparison of the biological effects produced by a given type of energy. This Relative Biological Effectiveness (RBE) ranges from 1 to 10, taking the gamma rays of radium or 200 KV X-rays as 1.

Some types of radiation tend to produce certain effects more readily than others. Thus, neutrons may produce cataracts as the most prominent change, strontium 90 and radium (when absorbed in the body) bone tumors, X-rays, skin cancer or leukemia.

In attempting to evaluate the effect of radiation, one must remember that there are few diseases or malfunctions produced solely and characteristically by radiation. Skin cancer can be produced in man by certain chemicals, ultraviolet light, irritation as well as by radiation. Leukemia may occur in 3 percent of a heavily irradiated population, but even higher among those exposed to benzol.

Some of the late atrophic changes of the skin and other tissues, some cataracts, some atrophic changes in bone can be recognized as almost certainly produced by radiation.

Bearing these variables in mind, and the great fallibility of attempting to particularize from general data, one may expect the following changes to develop in workers exposed to given doses of radiation.

25 r

Acute exposure:
- Immediate effects — Transient and minor blood cell changes.
- Late effects — None perceptible.

Protracted exposure — No effect.

100 r

Acute exposure:
- Immediate effects — Slight blood changes, probably both quantitative and qualitative. Slight nausea and vomiting in a few persons. Possible temporary reduction of fertility in some men or women. Very slightly increased chance of genetic defects in offspring.
- Late effects — Probably none except for very slightly increased chance of genetic defects in offspring.

Protracted exposure:
- Linear hypothesis — Probably no effect beyond a slightly greater likelihood of development of leukemia and possibly slight anemia. Very lightly increased chance of genetic defects in offspring.
- Threshold hypothesis — No effect on the individual. Very slightly increased chance of genetic defects in offspring.

200 r

Acute exposure:
- Immediate effects — Moderate changes in blood cells. Transient nausea and vomiting, mild diarrhea. A very few highly susceptible individuals might die, chiefly from damage to the blood-forming system. Slight transient epilation might occur in a few. Possible temporary reduction of fertility in some men or women. Very slightly increased chance of genetic defects in offspring.
- Late effects — Possibly some degree of persisting epilation. Slight possibility of development of leukemia, probably under 3 percent. Possibly slight anemia. Very slightly increased chance of genetic defects in offspring.

Protracted exposure:
- Linear hypothesis — Slightly greater likelihood of development of leukemia and other types of cancer and possibly slight anemia. Very slightly increased chance of genetic defects in offspring.
- Threshold hypothesis — Probably no effect.

	500 r
Acute exposure:	
Immediate effects	Marked blood cell changes. Severe nausea, vomiting, and diarrhea. Death in about ½ those exposed unless treated promptly. Some deaths in any event. Transient sterility. Moderately increased chance of genetic defects in offspring. Epilation.
Late effects	Persistence in disturbance of blood cells quantitatively and qualitatively for some months. Increased likelihood of leukemia and anemia, possibly up to 5 percent. Possible increase in likelihood of cancer. Some degree of persistent epilation. Sterility lasting up to about 2 years. Moderately increased chance of genetic defects in offspring.
Protracted exposure:	
Linear hypothesis	Probably none except moderately increased chance of development of leukemia, anemia, and possibly cancer. Moderately increased chance of genetic defects in offspring.
Threshold hypothesis	Slightly increased chance of leukemia, anemia, and possibly cancer. Moderately increased chance of genetic defects in offspring.
	600 r
Acute exposure	Severe nausea, vomiting, and diarrhea. Severe quantitative and qualitative damage to blood cells. Great weakness and lassitude. Death within days even with supportive treatment. All exposed individuals would probably die in spite of prompt supportive treatment.
Protracted exposure	No immediate effects. Some shortening of lifespan, probably under 5 years and an increased probability of leukemia or anemia, probably under 1 percent for each. Moderately increased chance of genetic defects in offspring.
	1,200 r
Acute exposure	Immediate disorientation and prostration with severe nausea, vomiting, and diarrhea, reddening and itching of the skin. Severe quantitative and qualitative damage to blood cells. Great weakness and lassitude. Death within days even with supportive treatment.
Protracted exposure	About 5 years shortening of lifespan. Greater likelihood of leukemia, perhaps up to 2 percent of exposed persons. Some increase in susceptibility to other types of cancer. Probably some anemia. Moderate increase in possibility of hereditary defects in offspring.

The permissible dose level established by the National Committee on Radiation Protection, an independent body of experts publishing through the National Bureau of Standards, is 5 rem for each year of the person's life over 18. Further, this should not exceed 12 rem in any one year. This a a lower level than that previously established, influenced by the fact that in recent years enough people are being exposed to radiation to have potential genetic significance for the race. The linear hypothesis is assumed to hold, and gence the benetic significance of 100 r of protracted total body radiation received by 10,000 people of child-bearing age is greater than that of 500 r received by 1,000 people. This current permissible dose is also based on the fact that as the number of exposed individuals increases the chance increases of some very susceptible individuals who may be injured at fairly low levels of radiation occurring among them.

If we assume the linear hypothesis, it is conceivable that a small number of persons of the many exposed might be damaged by long-continued low-level ex-

posure within the permissible dose range. If we assume the threshold hypothesis, no cases of radiation injury would be expected.

It should be remembered, however, that the permissible dose range is not meant to apply to the total population, including ill persons and the very young who may be more susceptible to injury, but rather is meant to apply only to adults working under conditions controlled from the standpoint of radiation and medical supervision.

One must keep in mind that there is probably no threshold for genetic damage, although the damage is probably so slight as to be not detectable at present permissible dose levels.

Thus, it may be seen that the probability of injury being noted in those cases where the dose received over a protracted period of time is equal to or less than the permissible level of radiation is so slight as to be in all probability negligible. If we assume a linear relationship, regardless of total amount of radiation and rate at which it is delivered, one could conceive of noticeable injury at this level in one or two of very many exposed. These statements are based on the use of plant or experimental animals in great numbers, where there is evidence that late injury can develop in a very few. The most probable type of injury would be the development of leukemia. There is no evidence of shortening of lifespan at present permissible dose levels.

Probably some genetic damage will be done, but this is too slight to detect by means available at present. There is slight evidence that some radiologists who have received much more than the present permissible does levels have had a slight increase of hereditary disease in their offspring.

It should be pointed out that ionizing radiation is only one of a number of mutogenic factors with which we come in contact in our lives today.

BASIS FOR COMPENSATION

Given a history of exposure to an excessive dose of radiation, either acute or protracted, and the presence of injury reasonably related to radiation, a sound basis for compensation is available. In some instances a small sum might be added to cover the possibility or probability of latent injury, the effects of which might not be manifest for some years to come.

If at the time of claim only a history of excessive exposure to radiation is given and evidence of injury is not present, only the chance of future damage can be considered. This problem is much more difficult. If the dose received is low, the probability of subsequent evidence of injury is so slight as to rule out consideration of future harm. If, on the other hand, the dose is large, the probability of future damage might be deemed sufficiently great to warrant a minor degree of advance compensation. Probably, however, the best approach is to compensate only for injury as it becomes clearly evident, maintaining if necessary a reserve fund to meet possible future claims for harm by exposure received earlier but only then apparent. As time goes on and experience is gained in this field, undoubtedly much better appraisal of risk can be made than at the present time.

Radiation is properly considered as a potential occupational risk but in the light of experience available thus far, it is a much smaller risk than that considered acceptable in many industries where ionizing radiation is not a factor.

APPENDIX E–1

COMPULSORY AND ELECTIVE TYPES OF LAWS

The jurisdictions with compulsory laws are:

Alaska	Maryland	Ohio
Arizona [1]	Massachusetts	Oklahoma
Arkansas	Michigan	Puerto Rico
California	Minnesota	Rhode Island
Delaware	Mississippi	Utah
District of Columbia	Nevada	Virginia
Hawaii	New Hampshire [1]	Washington
Idaho	New York	Wisconsin
Illinois	North Dakota	Wyoming

[1] Employee may reject act.

Longshoremen's and Harbor Workers' Compensation Act, Federal Employees' Compensation Act.

The jurisdictions with elective laws are:

Alabama	Louisiana	Oregon
Colorado	Maine	Pennsylvania
Connecticut	Missouri	South Carolina
Florida	Montana [2]	South Dakota
Georgia	Nebraska	Tennessee
Indiana [2]	New Jersey	Texas [4]
Iowa [3]	New Mexico	Vermont
Kansas	North Carolina	West Virginia
Kentucky		

[2] Compulsory as to coal mining.
[3] Compulsory as to operation of coal mines or production of coal for sale.
[4] Compulsory as to motorbus companies.

Appendix E–2

Type of Insurance Provisions

Jurisdictions limited to private insurance and self-insurance:

Alabama	Iowa	New Jersey
Alaska	Kansas	New Mexico
Arkansas	Kentucky	North Carolina
Connecticut	Louisiana	Rhode Island
Delaware	Maine	South Carolina
District of Columbia	Massachusetts	South Dakota
Florida	Minnesota	Tennessee
Georgia	Mississippi	Texas [1]
Hawaii	Missouri	Vermont
Illinois	Nebraska	Virginia
Indiana	New Hampshire	Wisconsin

Longshoremen's and Harbor Workers' Compensation Act.

Jurisdictions with State fund, private insurance, and self-insurance:

Arizona	Maryland	Oklahoma
California	Michigan	Pennsylvania
Colorado	Montana	Utah
Idaho	New York	

Jurisdictions limited to State funds:

Nevada	Oregon	West Virginia [2]
North Dakota	Puerto Rico	Wyoming
Ohio [2]	Washington	

[1] Self-insurance not permitted.
[2] Self-insurance permitted.

NOTE.—The Federal Employees' Compensation Act is financed by direct appropriation of Congress.

Appendix E–3

Numerical Exemptions

Jurisdictions making no numerical exemptions are:

Alaska	Louisiana	Pennsylvania
California	Maryland	Puerto Rico
District of Columbia	Minnesota	South Dakota
Hawaii	Montana	Utah
Idaho	Nebraska	Washington
Illinois	New Jersey	West Virginia
Indiana	North Dakota	Wyoming
Iowa	Oregon	

Longshoremen's and Harbor Workers' Compensation Act, Federal Employees' Compensation Act.

Jurisdictions providing for numerical exemptions are:

For employer with less than—	*Jurisdictions*
2 employees	Nevada,[1] Oklahoma.
3 employees	Arizona,[1] Connecticut, Delaware, Florida, Kentucky, Michigan,[1] Ohio, Texas, Wisconsin.
4 employees	Colorado, Massachusetts,[1] New Mexico,[2] New York,[3] Rhode Island.[1]
5 employees	Arkansas,[4] Kansas,[5] New Hampshire, North Carolina,[6] Tennessee.
6 employees	Maine, Vermont.
7 employees	Virginia.
8 employees	Alabama, Mississippi.[1]
10 employees	Georgia.
11 employees	Missouri.[7]
15 employees	South Carolina.

[1] Numerical exemption applies only to compulsory coverage.
[2] New Mexico: Does not apply if injury occurs upon any structure 10 feet or more above the ground.
[3] New York: Numerical exemption applies only in case of nonhazardous employments. However, the 14 groups of hazardous industries are so comprehensive that the numerical exemption seldom applies.
[4] Arkansas: Contractor engaged in building or building repair work is covered if he employs two or more employees at any one time. If contractor subcontracts any portion of work, contractor is covered if either the contractor or subcontractor has only one employee.
[5] Kansas: Numerical exemption does not apply to employment in mines and building construction.
[6] North Carolina: Act exempts individual sawmill and logging operators with less than 10 employees whose principal business is unrelated to sawmills and logging and who operate less than 60 days in 6 consecutive months.
[7] Missouri: If Workmen's Compensation Commission determines that employer of 10 or less employees is engaged in hazardous employment, such employer shall be covered unless he rejects act within 10 days.

Appendix E–4

Sample Provisions of Definitions of Term "Accidental Injury"

Arkansas: " 'Injury' means only accidental injury arising out of and in the course of employment * * *."

California: " 'Injury' includes any injury * * * arising out of the employment; including injuries to artificial members, dentures, eye glasses and medical braces of all types; provided, however, that eye glasses will not be replaced, repaired or otherwise compensated for, unless injury to them is incident to an injury causing disability."

Michigan: "* * * personal injury arising out of and in the course of his employment * * *."

New Jersey: "* * * personal injuries to, or for the death of, such employee by accident arising out of and in the course of his employement * * *."

New York: " 'Injury' and 'personal injury' mean only accidental injuries arising out of and in the course of employment * * *."

North Dakota: " 'Injury' shall mean only an injury arising in the course of employment * * *."

Washington: " 'Injury' means a sudden and tangible happening of a traumatic nature producing an immediate or prompt result, and occurring from without * * *."

Wisconsin: "* * * 'Injury' is mental or physical harm to an employee caused by accident * * *."

Appendix E–5

Coverage of Occupational Diseases

Jurisdictions which provide full coverage of occupational diseases are:

Alaska	Maryland	Oregon
Arkansas	Massachusetts	Pennsylvania
California	Michigan	Rhode Island
Connecticut	Minnesota	South Carolina
Delaware	Missouri	Utah
District of Columbia	Nebraska	Washington
Florida	New Jersey	West Virginia
Hawaii	Nevada	Wisconsin
Illinois	New York	Puerto Rico
Indiana	North Dakota	
Kentucky	Ohio	

Longshoremen's and Harbor Workers' Compensation Act, Federal Employees' Compensation Act.

Jurisdictions with schedule coverage of occupational diseases are:

Alabama	Kansas	Oklahoma
Arizona	Louisiana	South Dakota
Colorado	Maine	Tennessee [1]
Georgia	New Hampshire	Texas
Idaho	New Mexico	Vermont
Iowa	North Carolina	Virginia [1]

Jurisdictions with no coverage of occupational diseases are: Mississippi, Montana, Wyoming.

[1] Full coverage permissible.

Appendix E–6

Jurisdictions Which Include Radiation Diseases in Scheduled Coverage

Arizona: Ulcerations of the skin or destruction of tissue due to the prolonged exposure to Roentgen rays or radium emanations.

Arkansas: [1] Diseased condition caused by exposure to X-rays or radioactive substances.

Colorado: Poisoning or disease caused by exposure to radioactive materials, substances, or machines, or fissionable materials.

Georgia: Diseased condition caused by exposure to X-rays or radioactive substances.

Idaho: Radium poisoning by or disability due to radioactive properties of substance or to Roentgen ray (X-ray) in any occupation involving direct contact therewith, handling thereof, or exposure thereto.

Kansas: Diseased condition caused by exposure to X-rays or radioactive substances.

Louisiana: Diseased condition caused by exposure to X-rays or radioactive substances.

New Mexico: Ulceration of the skin or destruction of tissue due to prolonged exposure to Roentgen rays or radium emanations.

New York: [1] Radium poisoning or disability due to radioactive properties of substances or to Roentgen rays (X-rays) or exposure to ionizing radiation.

North Carolina: Radium poisoning or injury by X-rays.

Oklahoma: Diseased condition caused by exposure to X-rays or radioactive substances.

Puerto Rico: [1] Poisoning by radium and radioactive substances.

Pennsylvania: [1] Radium poisoning or disability due to radioactive properties of substances or to Roentgen ray (X-ray) in any occupation involving direct contact with, handling thereof, or exposure thereto.

Rhode Island: [1] Radium poisoning or disability due to radioactive properties of substances or to Roentgen rays (X-rays).

South Dakota: Ulceration of the skin or destruction of tissue due to the prolonged exposure to Roentgen rays or radium emanations.

[1] Full coverage of all occupational diseases is also provided.

Texas: Diseased condition caused by exposure to X-rays or radioactive substances.

Utah: [1] Ulceration of the skin or destruction of tissue due to the prolonged exposure to Roentgen rays or radium emanations.

Vermont: Diseased condition caused by exposure to X-rays or radioactive substances.

[1] Full coverage of all occupational diseases is also provided.

Appendix E–7

Coverage of radiation injuries under subsequent injury fund provisions of State workmen's compensation laws

State	Full coverage		State	Full coverage	
	Prior disability	Subsequent injury		Prior disability	Subsequent injury
Alabama [1]			Nevada [2]		
Arizona			New Hampshire [1]		
Arkansas			New Jersey	X [4]	X [5]
California	X	X	New Mexico [2]		
Colorado			New York	X	X
Connecticut			North Carolina		
Delaware	X	X [3]	North Dakota	X [7]	X
District of Columbia	X	X [3]	Ohio		X
Florida	X	X	Oklahoma	X [4]	X
Georgia [2]			Oregon		
Idaho			Pennsylvania		
Illinois			Rhode Island		
Indiana			South Carolina		
Iowa [1]			South Dakota		
Kansas			Tennessee [1]		
Kentucky	X [4]		Texas		
Louisiana [2]			Utah		
Maine [1]			Vermont		
Maryland			Virginia [2]		
Massachusetts	X [5]	X [6]	Washington	X	X [5]
Michigan			West Virginia	X	X [3]
Minnesota	X	X	Wisconsin	X	X
Mississippi [1]			Wyoming [1]		
Missouri	X	X	Alaska	X	X [3]
Montana [1]			Hawaii	X	X
Nebraska		X [3]	Puerto Rico	X	X [3]

[1] No radiation disease coverage in workmen's compensation law.
[2] Must result in permanent total disability.
[3] No second-injury fund provision in the law.
[4] Must be result of compensable injury or contracted in the Armed Forces while the United States was at war.
[5] Disability must result from military or naval service.
[6] Must be aggravated by preexisting military service-connected disability.
[7] Injury must be incurred in different employment.

Appendix E–8

Waivers

Waivers are not permitted in the following jurisdictions:

Alabama [1]	Louisiana	North Dakota
Alaska	Michigan	Oregon
Arizona	Mississippi	Pennsylvania
California	Missouri	Puerto Rico [1]
Delaware	Montana	Rhode Island
District of Columbia	Nebraska	Utah
Florida	New Jersey	Washington
Hawaii	New Mexico [1]	West Virginia
Kentucky	New York	Wyoming

[1] No provision in the law, waivers not permitted in practice, according to the State workmen's compensation agency.

Waivers are not permitted, except for special disabilities, in the following jurisdictions:

A. For aggravation of condition, generally upon approval of workmen's compensation agency:

Arkansas	Silicosis or asbestosis.[3]
Colorado	Occupational diseases.
Georgia	Silicosis or asbestosis.[3]
Idaho	Silicosis.[3]
Kansas	Occupational diseases.[3]
Minnesota	Occupational diseases.[3]
Nevada	Silicosis.[3]
North Carolina	Silicosis.[3]
Oklahoma	Silicosis.[3]
South Carolina	Occupational diseases.
South Dakota	Silicosis.[3]
Tennessee	Occupational diseases.
Texas	Silicosis or asbestosis.[3]
Vermont	Occupational diseases.
Virginia	Occupational diseases.

B. For other disabilities or conditions:

Indiana: No employee may waive the provisions of the occupational diseases act as to the amount of compensation payable except after approval by the Industrial Board.

Ohio: A blind employee may waive compensation for injury caused by his blindness.

Wisconsin: Epileptics and blind persons may elect not to be covered by the act for injuries resulting because of the blindness or epilepsy.

Waivers are permitted in the following jurisdictions:

Connecticut, for accidental injuries only, upon approval of the workmen's compensation agency.

Illinois, upon approval of the workmen's compensation agency.[4]

Iowa.

Maine, upon approval of the workmen's compensation agency.[4]

Maryland.

Massachusetts.[5]

New Hampshire, for accidental injuries only, upon approval of the workmen's compensation agency.

[3] In event of disability or death following waiver, limited amount of compensation, nevertheless, payable.
[3] A workman seeking employment may waive all claims for aggravation of his condition, a worker continuing in his employment and becoming disabled after a waiver will, nevertheless, receive limited benefits.
[4] According to the workmen's compensation agency, waivers have not at any time been permitted.
[5] However, veterans disabled by military or naval service may not waive their rights under the law.

APPENDIX E–9

Time limits for filing radiation disease claims under State workmen's compensation laws (covers limitations applicable to filing claims for radiation disease cases, except those resulting in death, under occupational disease provisions of workmen's compensation laws)

States	Date of worker's knowledge	Date of disablement	Date of manifestation of symptoms	Date of injury	Date of last exposure
Alabama	No radiation disease coverage.				
Alaska				2 years.	
Arizona		60 days [1]			
Arkansas					2 years.
California	1 year [2]				
Colorado		60 days [1]			
Connecticut			1 year.		
Delaware	1 year [2]				
District of Columbia				1 year.	
Florida				2 years.	
Georgia				1 year [4]	
Hawaii				6 months [4]	
Idaho		1 year.			
Illinois					3 years.

See footnotes at end of table, p. 00.

Time limits for filing radiation disease claims under State workmen's compensation laws (covers limitations applicable to filing claims for radiation disease cases, except those resulting in death, under occupational disease provisions of workmen's compensation laws)—Continued

States	Date of worker's knowledge	Date of disablement	Date of manifestation of symptoms	Date of injury	Date of last exposure
Indiana		2 years [6]			
Iowa	No radiation disease coverage				
Kansas		1 year [7]			
Kentucky			1 year [8]		
Louisiana			4 months [9]		
Maine	No radiation disease coverage				
Maryland		1 year [7]			
Massachusetts				6 months [10]	
Michigan				3 years	
Minnesota				6 years [11]	
Mississippi	No radiation disease coverage				
Missouri				1 year	
Montana	No coverage of occupational diseases in Workmen's Compensation law.				
Nebraska				6 months [12]	
Nevada		4 months			
New Hampshire	No radiation disease coverage				
New Jersey	1 year [13]				
New Mexico		60 days			
New York	90 days [14]				
North Carolina		1 year			
North Dakota				1 year	
Ohio		6 months			
Oklahoma				1 year	
Oregon		3 months [15]			
Pennsylvania		16 months			
Puerto Rico [16]					
Rhode Island		24 months			
South Carolina					1 year.
South Dakota		1 year			
Tennessee [17]					
Texas			6 months [18]		
Utah		60 days [19]			
Vermont					2 years.
Virginia [17]					
Washington	1 year [20]				
West Virginia				1 year	
Wisconsin	2 years [21]				
Wyoming	No coverage of occupational diseases				

[1] Disability must result within 120 days from exposure.
[2] 1 year from the date on which employee first suffered disability and knew or should have known that his disability was caused by the job.
[3] Within 1 year after knowledge and 5 years after last exposure.
[4] Disablement must result within 1 year after last exposure.
[5] May be waived if employer not prejudiced thereby.
[6] Claim must be filed within 2 years after disablement and disablement must occur within 2 years after last exposure.
[7] Claim must be filed within 1 year after disablement and disablement must occur within 1 year after the last injurious exposure, but failure to file within such time limits may be waived under certain circumstances.
[8] 1 year after employee first experiences a distinct manifestation of an occupational disease or after date of last exposure, whichever date is later.
[9] Notice to employer within 4 months of contraction of disease or 4 months of manifestation constitutes claim.
[10] Within 6 months "after its occurrence." However, failure to make a claim within the 6 months shall not bar proceedings under certain circumstances.
[11] 2 years after employer reports occupational disease to commission, but not to exceed 6 years from date of accident. Disease must be contracted in employment within 12 months previous to date of disablement.
[12] Within 6 months from date of injury and disability must have commenced within 2 years subsequent to the date of termination of the employment.
[13] Within 1 year after the employee knew or ought to have known the nature of his disability and its relation to his employment and within 5 years after exposure.
[14] 90 days after knowledge that the disease was due to the nature of the employment and after disablement.
[15] Within 3 months from the date the claimant becomes disabled and within 3 years after last exposure.
[16] No time limit provision.
[17] Radiation diseases not covered by schedule, but full coverage may be elected. If elected, claim must be filed in Virginia within 1 year after the employee first experiences a distinct manifestation or a diagnosis of such disease is first communicated to him, which ever shall first occur, and in Tennessee 1 year after date of disablement.
[18] In meritorious cases, strict compliance may be waived.
[19] Within 60 days after cause of action.
[20] 1 year from date claimant has notice from physician of his occupational disease.
[21] Within 2 years after the employee knew or ought to have known the nature of his disability and its relation to his employment.

APPENDIX E–10

SAMPLE PROVISIONS OF TIME LIMITS FOR FILING CLAIMS

California

The date of injury in cases of occupational diseases is that date upon which the employee first suffered disability therefrom and either knew, or in the exercise of reasonable diligence should have known, that said disability was caused by his present or prior employment.

No * * * proceedings [for the collection of benefits] may be commenced more than 1 year after the date of death, nor more than 240 weeks from the date of injury.

Florida

The right to compensation for disability under this chapter shall be barred unless a claim therefor is filed within 2 years after the time of injury, except that if payment of compensation has been made or remedial treatment has been furnished by the employer without an award on account of such injury a claim may be filed within 2 years after the date of last payment of compensation or after the date of the last remedial treatment furnished by the employer.

Idaho

Unless written notice of the manifestation of an occupational disease shall be given by the workman to the employer within 60 days after the first manifestation thereof, and except in the case of silicosis within 5 months after the employment has ceased in which it is claimed the disease was contracted, and, in case of death, unless written notice of such death shall be given within 90 days after the occurrence, and, unless claim for disability, or death, shall be made within 1 year after the disablement, or death, respectively, all rights to compensation for disability, or death, from an occupational disease shall be forever barred.

Kentucky

The right to compensation under this act for disability resulting from an occupational disease shall be forever barred unless a claim is filed with the Workmen's Compensation Board within 1 year after the last injurious exposure to the occupational hazard or after the employee first experiences a distinct manifestation of an occupational disease in the form of symptoms reasonably sufficient to apprise him that he has contracted the disease, whichever shall last occur * * *.

New York

* * * The right of an employee to claim compensation under this chapter for disablement caused by compressed air illness or its sequelae, or by latent or delayed pathological bone, blood, or lung changes or malignancies due to occupational exposure to or contact with arsenic, benzol, beryllium, cadmium, chrome, lead, or fluorine or to exposure to X-rays, radium or radioactive substances, shall not be barred by the failure of the employee to file a claim within such period of 2 years, provided such claim shall be filed after such period of 2 years and within 90 days after disablement and after knowledge that the disease is or was due to the nature of the employment * * *.

Appendix E–11

Medical Benefits

Jurisdictions which provide full medical benefits, by law or by administrative authority, for both accidental injuries and occupational diseases [1]

California	Michigan	Ohio
Connecticut	Minnesota	Oklahoma
Delaware	Missouri	Oregon
District of Columbia	Nebraska	Pennsylvania
Florida	New Hampshire	Puerto Rico
Hawaii	New Jersey	Rhode Island
Idaho	New Mexico	South Carolina
Indiana	New York	Washington
Maryland	North Carolina	Wisconsin
Massachusetts	North Dakota	

[1] Mississippi and Wyoming provide full medical benefits for accidental injuries. The workmen's compensation laws in these States do not provide coverage of occupational diseases.

Federal Employees' Compensation Act, Longshoremen's and Harbor Workers' Compensation Act.

Jurisdictions which limit medical benefits (a) in all cases or (b) in special cases

States	(a) Benefits limited in all cases		(b) Benefits limited in special cases	
	Limited by time	Limited by amount	Limited by time	Limited by amount
Alabama	6 months	$1,200		
Alaska	4 years			
Arizona				$1,000 for total disability from occupational diseases generally; $500 if employee able to continue work while being treated for specified diseases including radiation diseases.
Arkansas			90 days for silicosis and asbestosis; may be extended for an additional 90 days.	$250 for hernia.
Colorado	6 months	$1,500		
Georgia		$1,125, plus $375 in discretion of Board.		
Illinois			6 months for silicosis or asbestosis or either complicated by tuberculosis.	
Iowa		$500 for medical and surgical services; $1,000 for hospital services and supplies; full payment for special nurses and ambulance charges. Commission may authorize an additional $1,000.		
Kansas	120 days; in extreme cases, Commissioner may extend time.	$2,500	For silicosis Commissioner may extend the 120-day limit by 90 days if there is substantial prospect that such continued treatment will materially improve employee's condition.	
Kentucky		$2,500		
Louisiana		$2,500		
Maine				$1,000 for silicosis.
Montana	36 months	$2,500. In cases of total disability where the $2,500 is insufficient to meet all hospital expenses, additional hospital and medical expenses may be allowed in special cases.		
Nevada	(Applies to accident cases only. No coverage of occupational diseases in the workmen's compensation law.)			(1).

South Dakota	20 weeks	$300 for medical and surgical services; $700 for hospital benefits including prostheses.		
Tennessee	1 year	$1,500		
Texas			91 days for silicosis or asbestosis	
Utah				$1,283.33 for occupational diseases; Commission may increase to $1,925.01 in cases of prolonged hospitalization.
Vermont		$2,500	3 years for silicosis or asbestosis	$500 for silicosis or asbestosis.
Virginia	60 days; may be extended for 1 year including the 1st 60 days. No limit in hernia cases.			
West Virginia	$1,600 additional, $800 may be authorized.		No allowance for medical treatment for silicosis.	

[1] Total payable for compensation, medical nursing, and hospital benefits for silicosis may not exceed $11,250.

3434—59——11

APPENDIX E–12

Selection of doctor under State workmen's compensation laws

State	Choice by worker	Choice by employer or insurance carrier	Change may be ordered by workmen's compensation agency
Alabama		X	
Arizona	X		X
Arkansas		X	X
California	X [1]		
Colorado		X	X
Connecticut		X	X
Delaware		X	X
District of Columbia		X	
Florida		X	X
Georgia		X	X
Idaho		X	X
Illinois		X	X
Indiana		X	X
Iowa		X	
Kansas		X	X
Kentucky		X	X
Louisiana		X	
Maine		X	
Maryland		X	
Massachusetts	X		
Michigan		X	
Minnesota	X		X
Mississippi		X	
Missouri		X	X
Montana	X		X
Nebraska		X [2]	X [2]
Nevada		X	X
New Hampshire	X		
New Jersey		X	
New Mexico		X	
New York	X [3]		
North Carolina		X	X
North Dakota	X		X
Ohio	X [4]		X [5]
Oklahoma		X	X
Oregon	X		X
Pennsylvania		X	X
Rhode Island	X		
South Carolina		X	X
South Dakota		X	
Tennessee	X [6]		
Texas		X	X
Utah		X	X
Vermont		X [7]	
Virginia		X	X
Washington	X		X
West Virginia	X		
Wisconsin	X [8]		X
Wyoming	X		
Alaska		X	
Hawaii	X		X
Puerto Rico		X	X

[1] On request from list of 3 nominated by employer.
[2] Employee may select for dismemberment or major operation.
[3] From panel authorized by the Workmen's Compensation Board.
[4] Except where employer is self-insured.
[5] Employee may choose from a panel of at least 3 chosen by Industrial Commission.
[6] From panel of 3 nominated by employer.
[7] Employee may select his own physician upon written notice to employer if dissatisfied with physician selected by employer.
[8] From panel named by employer.

APPENDIX E–13

Chart showing ratio of maximum weekly benefit for temporary total disability to average weekly wages by State [1]

State	Maximum weekly temporary total disability benefit—single worker and worker with dependents where law makes no provision for dependency allowances	Maximum weekly temporary total disability benefit—worker, wife, and 2 dependent children where additional compensation allowed for dependents	Average weekly wage	Ratio maximum weekly temporary total disability benefit for worker, wife, and 2 dependent children to average weekly wage [1]
				Percent
Alabama	$31.00	----	$69.22	44.8
Arizona	150.00	$156.90	83.20	188.6
Arkansas	35.00	----	57.81	60.5
California	50.00	----	93.30	53.5
Colorado	36.75	----	83.43	44.0
Connecticut	45.00	----	88.95	50.6
Delaware	35.00	----	93.51	37.4
District of Columbia	54.00	----	80.20	67.3
Florida	35.00	----	71.22	49.1
Georgia	30.00	----	65.23	46.0
Idaho	28.00	41.00	75.26	54.5
Illinois	39.00	42.00	93.56	44.9
Indiana	36.00	----	88.19	40.8
Iowa	32.00	----	76.04	42.1
Kansas	34.00	----	79.29	42.9
Kentucky	32.00	----	74.14	43.2
Louisiana	35.00	----	76.53	45.7
Maine	35.00	----	69.37	50.5
Maryland	40.00	----	77.35	51.7
Massachusetts	40.00	52.00	77.75	66.9
Michigan	33.00	45.00	99.41	45.3
Minnesota	45.00	----	81.49	55.2
Mississippi	35.00	----	57.54	60.8
Missouri	37.50	----	80.52	46.6
Montana	28.00	36.50	77.84	46.9
Nebraska	34.00	----	72.35	47.0
Nevada	37.50	51.92	90.57	57.3
New Hampshire	37.00	----	69.11	53.5
New Jersey	40.00	----	90.74	44.1
New Mexico	30.00	----	78.16	38.4
New York	45.00	----	91.25	49.3
North Carolina	35.00	----	61.48	56.9
North Dakota	31.50	37.10	71.09	52.0
Ohio	40.25	----	92.21	43.7
Oklahoma	35.00	----	77.89	44.9
Oregon	30.00	48.46	84.47	57.6
Pennsylvania	37.50	----	82.26	45.6
Rhode Island	32.00	----	72.01	44.4
South Carolina	35.00	----	59.69	58.6
South Dakota	30.00	----	68.87	43.6
Tennessee	32.00	----	69.99	45.7
Texas	35.00	----	78.31	44.7
Utah	35.00	39.90	78.17	51.0
Vermont	30.00	34.00	69.66	48.8
Virginia	33.00	----	68.63	48.1
Washington	28.85	48.46	86.98	55.7
West Virginia	33.00	----	85.33	38.7
Wisconsin	49.00	----	85.54	57.3
Wyoming	30.00	42.46	76.71	55.4
Alaska	100.00	----	131.06	76.3
Hawaii	75.00	----	65.38	114.7
Puerto Rico	25.00	----	----	----

[1] Maximum weekly benefits based on worker, wife, and 2 dependent children. Average wages based on wage of workers covered under unemployment insurance laws.

APPENDIX E–14

Minimum and maximum benefits for temporary total disability

State	Maximum percentage of wages	Maximum period	Payments per week		Total maximum stated in law
			Minimum	Maximum	
Alabama	[1] 55–65	300 weeks	$5.00, or average wage if less	$31.00	
Alaska	65	24 months	No statutory minimum	$100.00	
Arizona	[2] 65	433 weeks	No statutory minimum	$150.00, plus $2.30 for each total dependent.	
Arkansas	65	450 weeks	$7.00	$35.00	$12,500.
California	[3] 61¼	240 weeks	$15.00	$50.00	$12,000.
Colorado	66⅔	Period of disability	$10.00	$36.75	
Connecticut	60	do	$15.00	$45.00	
Delaware	66⅔	do	$18.00, or actual wage if less	$35.00	
District of Columbia	66⅔	do	$18.00, or average wage if less	$54.00 [4]	$17,280.
Florida	60	350 weeks	$8.00, or actual wage if less	$35.00	
Georgia	60	400 weeks	$10.00, or actual wage if less	$30.00	$10,000.
Hawaii	66⅔	Period of disability	$18.00, or average wage if less	$75.00	$25,000.
Idaho	[1] 55–65	400 weeks; [5] thereafter $12 per week ($15 if dependent wife) for period of disability, plus $4–$15 for children.	$12.00–$27.00 [1]	$28.00–$48.00 [1]	
Illinois	[1] 75–97½	Period of disability	$19.50–$33.00 [1]	$39.00–$45.00 [1]	[1] $10,750–$13,500.
Indiana	60	500 weeks	$18.00, or average wage if less	$36.00	$15,000.
Iowa	66⅔	300 weeks	$15.00, or actual wage if less	$32.00	
Kansas	60	416 weeks	$7.00	$34.00	
Kentucky	65	425 weeks	$12.00	$32.00	$13,600.
Louisiana	65	300 weeks	$10.00, or actual wage if less	$35.00	
Maine	66⅔	500 weeks	$15.00	$35.00	$14,000.
Maryland	66⅔	312 weeks	$18.00, or actual wage if less	$40.00	$5,000.
Massachusetts	66⅔	Period of disability	$20.00, or average weekly wage if less, but not less than $10 if normal working hours are 15 or more.	$40; plus $4 for each total dependent. [3]	$12,000, plus dependents' allowances.
Michigan	66⅔	500 weeks	$18.00–$28.00 [1]	$33.00–$57.00 [1]	([6]).
Minnesota	66⅔	350 weeks [4]	$17.50	$45.00	
Mississippi	66⅔	450 weeks	$10.00	$35.00	$12,500.
Missouri	66⅔	400 weeks	$16.00, or actual wage if less	$37.50	
Montana	[1] 50–66⅔	300 weeks	$25.50	$28.00–$42.50 [1]	
Nebraska	66⅔	300 weeks; [5] thereafter 45 percent of wages, maximum $27.50.	$20.00, first 300 weeks; thereafter $17 or actual wage if less.	$34.00	
Nevada	[1] 65–90	433 weeks	No statutory minimum	$37.50–$51.92 [1]	
New Hampshire	66⅔	341 weeks	$15.00, or average wage if less	$37.00	$12,617.
New Jersey	([7])	300 weeks	$10.00	$40.00	
New Mexico	60	550 weeks	$17.00, or actual wage if less	$30.00	
New York	66⅔	Period of disability	$20.00, or actual wage if less	$45.00	$6,000.
North Carolina	60	400 weeks	$10.00	$35.00	$10,000.

New York	66⅔	Period of disability	$15.00	$35.00	[1] $10,000.
North Carolina	60	400 weeks	$10.00		
North Dakota	80	Period of disability	$15.00, plus $2.80 for each child, but total may not exceed actual wage.	$31.50–$45.50 [1]	
Ohio	66⅔	520 weeks	$14.00, or actual wage if less	$40.25	$8,000.
Oklahoma	66⅔	300 weeks; may be extended to 500 weeks	$15.00, or actual wage if less	$35.00	
Oregon	[1] 50–75	Period of disability	Same as maximum, or actual wage if less	$30.00–$66.92 [1]	
Pennsylvania	66⅔	do	$25.00, or 90% of actual wage if less but in no event less than $15.	$37.50	
Puerto Rico	60	312 weeks	$5.00	$25.00	
Rhode Island	60	Period of disability [6]	$17.00	$32.00	([5]).
South Carolina	60	500 weeks	$5.00	$35.00	$10,000.
South Dakota	55	312 weeks	$15.00, or average wage if less	$30.00	
Tennessee	65	300 weeks	$15.00, or average wage if less, but in no event less than $12.	$32.00	
Texas	60	401 weeks	$9.00	$35.00	
Utah	60	312 weeks	$22.75–$30.71,[1] or actual wage if less	$35.00–$47.25 [1]	[1] $10,010–$13,513.50.
Vermont	66⅔	330 weeks [3]	$18.00, or average wage if less	$30.00, plus $2 for each dependent child under 21.	$9,900.
Virginia	60	500 weeks	$6.00	$33.00	$13,200.
Washington		Period of disability	Same as maximum	$28.85–$56.77 [1]	
West Virginia	66⅔	208 weeks	$20.00	$33.00	
Wisconsin	70	Period of disability	$8.75	$49.00 [4]	
Wyoming		do	$30.00–$46.15 [1]	$30.00–$46.15 [1]	
United States: Federal employees	[1] 66⅔–75	do	$25.96, or actual wage if less	$121.15 [4]	
Longshoremen	66⅔	do	$18.00, or average wage if less	$54.00 [4]	$17,280.

[1] According to number of dependents. In Idaho, Oregon, Washington, and Wyoming, according to marital status and number of dependents.
[2] Additional benefits for dependents.
[3] The California law provides for 65 percent of 95 percent of actual earnings, or 61¾ percent.
[4] Additional benefits in specific cases, such as rehabilitation, constant attendant, etc.
[5] In case total disability begins after a period of partial disability, the period of partial disability shall be deducted from the specified period for temporary total.
[6] Michigan: not to exceed 500 times total weekly amount payable.
[7] New Jersey: benefits set in accordance with a "wage and compensation schedule."
[8] Rhode Island: after 1,000 weeks, or after $16,000 has been paid, payments to be made from second-injury fund for period of disability.

APPENDIX E-15

Minimum and maximum benefits for permanent partial disability

State	Maximum percentage of wages or wage loss [1]	Maximum period, nonschedule injuries [17]	Payments per week [2]		Total maximum stated in law [2]
			Minimum	Maximum	
Alabama	55–65 according to number of dependents.	300 weeks	$5.00, or actual wage if less (schedule). No statutory minimum for nonschedule.	$31.00	$12,400 (schedule).
Alaska [3]					$12,400 (schedule).
Arizona	55	During disability [4]	No statutory minimum	$26.92	
Arkansas	65	450 weeks [5]	$7.00	$35.00	$12,500.
California	61¾ [6]	399 weeks [5 7]	$15.00	$40.00	
Colorado	66⅔	During disability [8]	$10.00	$36.75	$9,555 (nonschedule).
Connecticut	60	780 weeks [5]	$15.00 (schedule). No statutory minimum for nonschedule.	$45.00	
Delaware	66⅔	300 weeks [5]	$18.00, or actual wage if less (schedule). No statutory minimum for nonschedule.	$35.00	
District of Columbia	66⅔	During disability [5]	No statutory minimum	$54.00 [9]	$17,280.
Florida	60	350 weeks [5]	$8.00 or actual wage if less	$35.00	
Georgia	60	350 weeks [4]	$10.00, or actual wage if less (schedule). No minimum for nonschedule.	$30.00 (schedule) $20.00 (nonschedule)	$6,000 (nonschedule).
Hawaii	66⅔	During disability [5]	$18.00, or average if less, but in case of disability of minor not less than $18.	$75.00 [9]	$25,000.
Idaho	60	In proportion to schedule injuries. [5]	$12.00, or average if less (schedule). No minimum for nonschedule.	$25.00	
Illinois	75–97½ according to number of dependents (schedule). 65–80 (nonschedule).	417 weeks [4]	$19.50–$33.00 according to number of dependents.	$39.00–$45.00 according to number of dependents.	$10,750–$13,500 according to number of dependents.
Indiana	60	500 weeks [9]	$18.00, or average wage if less.	$36.00	$15,000.
Iowa	66⅔	In proportion to schedule injuries.	$15.00, or actual wage if less.	$32.00	
Kansas	60	415 weeks	No statutory minimum	$34.00	
Kentucky	65	400 weeks [10]	$12.00	$26.00 (schedule) $27.00 (nonschedule)	$10,800 (nonschedule).
Louisiana	65	300 weeks	$10.00, or actual wage if less	$35.00	
Maine	66⅔	do	No statutory minimum	$35.00	
Maryland	66⅔	During disability [4]	$15.00, or actual wage if less	$25.00	$12,500 (schedule). $7,500 (nonschedule).

Louisiana	65	300 weeks	No statutory minimum	$35.00	
Maine	66⅔	do	No statutory minimum	$35.00	$12,500 (schedule).
Maryland	66⅔	During disability [5]	$15.00, or actual wage if less	$25.00	$7,500 (nonschedule).
Massachusetts	66⅔	During disability	No statutory minimum	$40.00 plus $4 for each dependent (aggregate of dependents' benefits shall not exceed the average weekly wage of the employee).[11]	$12,000 plus dependents' allowances.
Michigan	66⅔	500 weeks	do	$33.00–$57.00 according to number of dependents.	
Minnesota	66⅔	350 weeks [5]	$17.50	$45.00 [5]	
Mississippi	66⅔	450 weeks [5]	$10.00 (schedule)	$35.00	$12,500.
Missouri	66⅔	400 weeks [5]	$16.00	$37.50	
Montana	50–66⅔, according to number of dependents.	500 weeks	$25.50 (schedule). No statutory minimum for nonschedule.	$28.00–$42.50 according to number of dependents.	
Nebraska	66⅔	300 weeks [4]	$20.00, or actual wage if less (schedule). No statutory minimum for nonschedule.	$34.00	
Nevada	50	429 weeks [5]	$11.54	$20.77	
New Hampshire	66⅔	341 weeks [4]	$20.00, or average wage if less (schedule). $12.00 (nonschedule.	$37.00	
New Jersey	(12)	550 weeks [5]	$10.00	$35.00	
New Mexico	60	In proportion to schedule injuries.[4]	$17.00, or actual wage if less (schedule).	$30.00	
New York	66⅔	During disability	$20.00, or actual wage if less	$45.00 [5]	
North Carolina	60	300 weeks	$10.00 (schedule). No statutory minimum for nonschedule.	$35.00	$10,000.
North Dakota	66⅔	450 weeks	$31.50	$31.50	
Ohio	66⅔	No period designated in law. [13]	$14.00 (schedule). No statutory minimum for nonschedule.	$40.25 [5]	$7,500, Division A.[13] $8,050, Division B.[13] $10,000 aggregate maximum for all permanent partial benefits.
Oklahoma	66⅔	500 weeks	$15.00, or actual wage if less	$30.00	
Oregon	50–75 according to number of dependents.	In proportion to schedule injuries.[5]	$23.08	$30.00–$66.92 according to number of dependents.[14]	$6,742.50 (nonschedule).
Pennsylvania	66⅔	350 weeks [5]	No statutory minimum	$37.50 (schedule) $27.50 (nonschedule)	
Puerto Rico	60	([5] 15)	$6.00 (schedule). No statutory minimum for nonschedule.	$22.00	$4,000 or $5,000.[15]
Rhode Island	50 (schedule) 60 (nonschedule)	800 weeks	$12.00 (schedule) No statutory minimum for nonschedule.	$24.00 (schedule) $22.00 (nonschedule).[16]	
South Carolina	60	300 weeks [5]	$5.00 (schedule). No statutory minimum for nonschedule.	$35.00	$10,000.
South Dakota	55 (schedule) 50 (nonschedule)	312 weeks [5]	$15.00, or average wage if less (schedule). No statutory minimum for nonschedule.	$30.00	

See footnotes at end of table, p. 158.

APPENDIX E–15—Continued

Minimum and maximum benefits for permanent partial disability—Continued

State	Maximum percentage of wages or wage loss [1]	Maximum period, nonschedule injuries [17]	Payments per week [2]		Total maximum stated in law [2]
			Minimum	Maximum	
Tennessee	65	400 weeks [3]	$15.00, or average wage if less, but in no event less than $12.	$32.00	$11,000.
Texas	60	300 weeks [5]	No statutory minimum	$35.00	
Utah	60	312 weeks [4]	do	$35.00–$47.25 according to number of dependents.	$8,020.86.
Vermont	66⅔	330 weeks [4]	$18.00, or average wage if less (schedule). No statutory minimum for nonschedule.	$30.00 (schedule) plus $2 for each dependent child under 21.[3]	$9,900.[4]
				$18.00 (nonschedule)	
Virginia	60	300 weeks [4]	$6.00 (schedule). No statutory minimum for nonschedule.	$33.00	$13,200.
Washington		In proportion to schedule injuries.	No statutory minimum	In proportion to schedule injuries.	$7,500 (nonschedule).
West Virginia	66⅔	336 weeks [4]	$20.00	$33.00	
Wisconsin	70	1,000 weeks [6]	$14.00	$37.00 [6]	
Wyoming		In proportion to schedule injuries.[3]	$20.77–$25.38 according to marital status.	$20.77–$25.38 according to marital status.	
United States: Federal employees.	66⅔–75 according to number of dependents.	During disability [8]	$25.96, or actual wage if less	$121.15 [8]	
Longshoremen	66⅔	do	No statutory minimum	$54.00 [8]	$17,280.

[1] Generally for schedule injuries percentage is figured on average weekly wages, and for nonschedule injuries on the basis of difference between wages before injury and wages after injury.

[2] Figure given is the amount paid for both schedule and nonschedule injuries unless otherwise noted. For further information on schedule injuries, see appendix E–16.

[3] Alaska: Benefits for schedule injuries are fixed sums ranging from $300 to $7,200 and varying according to marital status and number of dependents; for nonschedule injuries benefits are in proportion to permanent total injuries, but may not exceed a total of $14,400.

[4] In case the partial disability begins after a period of total disability, the period of total disability shall be deducted from the partial.

[5] In addition to compensation for temporary total disability, which is limited in some States to a specific number of weeks.

[6] The California law provides for 65 percent of 95 percent of actual earnings, or 61¾ percent.

[7] California: 4 weeks of compensation for each 1 percent of permanent disability, and thereafter if disability is 70 percent or more, life pension of 1 percent of average weekly earnings for each 1 percent of disability in excess of 60 percent.

[8] Additional benefits in specified cases, such as vocational rehabilitation, constant attendant, etc.

[9] Payments are in lieu of all other payments.

[10] Kentucky: Where compensation is paid for other types of disability, the period of such payments is deducted from the 400 weeks.

[11] In Massachusetts $20 a week is paid for schedule injuries in addition to all other benefits. See appendix E–16.

[12] New Jersey: Benefits set in accordance with a "wage and compensation schedule".

[13] Ohio: Benefits based on percentage of earning capacity impairment (called "Division A" in law) or of permanent physical impairment ("Division B") upon election of employee.

[14] Oregon: Schedule permanent partial injuries are compensated at the rate of $46.50 for each degree of disability, as specified in the law, but maximum weekly payments limited to those shown in this table. (See appendix E–16, footnote 25.)

[15] Puerto Rico: Period not specified if graded in proportion to schedule injuries. 450 weeks if graded in proportion to permanent total disability. The total maximum is $4,000 for schedule injuries and for nonschedule injuries graded in proportion to schedule injuries, and $5,000 for nonschedule injuries graded in proportion to permanent total disability.

[16] Rhode Island: If employee cannot obtain suitable work and employer cannot give him such work or show it is available elsewhere, weekly benefits for partial incapacity are paid at the same rate as for total incapacity ($32 maximum).

[17] For maximum period for schedule injuries, see appendix E–16.

[8] Additional benefits in specified cases, such as vocational rehabilitation, constant attendant, etc.
[9] Payments are in lieu of all other payments.
[17] For maximum period for schedule injuries, see appendix E–16.

Appendix E–16

Number of weeks for which compensation is payable for schedule injuries (Monetary weekly benefits shown on Appendix E–15)

State	Loss or loss of use of—													
	Arm (at shoulder)	Hand	Thumb	1st finger	2d finger	3d finger	Little finger	Leg	Foot	Great toe	Other toe	Sight of eye	Hearing, 1 ear	Hearing, both ears
Alabama [1]	200	150	60	45	30	20	15	175	125	30	10	100	50	150
Alaska [2] [9]														
Arizona [3]	[4] 260 [5] 217	[4] 217 [5] 173	65	39	30	22	17	217	173	30	11	[6] 130 [7] 108	87	260
Arkansas [3]	[5] 200	150	60	35	30	20	15	[9] 175	125	30	10	100	40	150
California [3] [10]	[4] 300 [5] 280	[4] 280 [5] 260	[4] 48 [5] 44	[4] 32 [5] 28	[4] 32 [5] 28	[4] 24 [5] 20	[4] 24 [5] 20	[10] 320 [11] 260	140	40	8	[6] 120 [7] 100	40	200
Colorado [3]	208	104	[12] 50 [13] 35	[12] 26 [13] 18	[12] 18 [13] 13	[12] 11 [13] 7	[12] 13 [13] 9	[14] 208 [11] 139	104	[12] 26 [13] 18	[12] 11 [13] 4	[6] 139 [7] 104	35	139
Connecticut [3]	[5] 275	232	75	48	38	25	20	[9] 208	156	38	13	208	52	186
Delaware [3]	[5] 250	220	75	50	40	30	20	250	160	40	15	200	75	175
District of Columbia [3]	[5] 312	244	75	46	30	25	15	[9] 288	205	38	16	160	52	200
Florida [3]	[5] 200	175	60	35	30	20	15	[9] 200	175	30	10	175	40	150
Georgia [3]	200	150	60	40	35	30	25	225	125	20	20	125	50	150
Hawaii [3]	312	244	75	46	30	25	15	[5] 288	205	38	16	[6] 160 [7] 140	52	200
Idaho [3]	240	200	[12] 70 [13] 40	[12] 40 [13] 35	[12] 40 [13] 30	[12] 30 [13] 20	[12] 20 [13] 15	[14] 180 [11] 150	125	[12] 30 [13] 15	[12] 12 [13] 6	[6] 140 [7] 120	35	115
Illinois [3]	[13] 300	190	70	40	35	25	20	[13] 275	155	35	12	[6] 150 [7] 140	50	125
Indiana [16]	[5] 250	200	60	40	35	30	20	[9] 200	150	60	(17)	150	75	200
Iowa [3]	230	175	60	35	30	25	20	[9] 200	150	40	15	125	50	175
Kansas [10]	210	150	60	37	30	20	15	[9] 200	125	30	10	120	30	110
Kentucky [3]	200	150	[12] 70 [13] 60	[12] 55 [13] 45	[12] 40 [13] 30	[12] 30 [13] 20	[12] 25 [13] 15	200	125	30	10	[6] 120 [7] 100	75	150
Louisiana [1]	200	150	50	30	20	20	20	[9] 175	125	20	10	100		
Maine [19]	175	150	50	32	28	20	17	[9] 175	150	25	10	[20] 100	50	100
Maryland [3]	[5] 252	196	50	30	25	20	15	[9] 252	175	25	10	200	75	175
Massachusetts [21]	[4] [5] 175 [5] [5] 150	[4] [5] 125 [5] [5] 100						[9] 175	125			[5] 200	100	200
Michigan [3]	[5] 209	215	65	38	33	22	16	[9] 215	162	33	11	162		
Minnesota [3]	[5] 270	220	65	40	35	25	20	[14] 220 [11] 195	165	35	15	160	55	170
Mississippi [3]	[5] 200	150	60	35	30	20	15	[9] 175	125	30	10	100	40	150
Missouri [3]	232	175	60	45	35	35	22	[14] 207 [11] 160	150	40	14	140	44	168
Montana [1]	280	200	[13] 75 [13] 37	[13] 75 [13] 30	[13] 37 [13] 20	[13] 25 [13] 15	[13] 15 [13] 11	[14] 300 [11] 200	180	[12] 37 [13] 18	[13] 16 [13] 8	[6] 165 [7] 140	40	200

See footnotes at end of table, p. 161.

APPENDIX E–16—Continued

Number of weeks for which compensation is payable for schedule injuries (Monetary weekly benefits shown on Appendix E–15)—Continued

State	Loss or loss of use of—													
	Arm (at shoulder)	Hand	Thumb	1st finger	2d finger	3d finger	Little finger	Leg	Foot	Great toe	Other toe	Sight of eye	Hearing, 1 ear	Hearing, both ears
Nebraska [3]	[6] 225	175	60	35	30	20	15	[6] 215	150	30	10	125	50	100
Nevada [3]	[4] 260 [5] 217	[4] 217 [5] 173	65	39	30	22	17	[6] 217	173	30	11	[6] 130 [7] 108	87	260
New Hampshire [22]	[6] 214	175	50	31	26	19	13	[6] 214	151	26	10	126	52	214
New Jersey [3]	[6] 300	230	75	50	40	30	20	[6] 275	200	40	15	[6] 225 [7] 200	60	200
New Mexico [3]	[4] 180 [5] 160	[4] 110 [5] 100	[12] 50 [12] 30	[12] 25 [12] 20	[12] 20 [12] 15	[12] 15 [12] 10	[12] 12 [12] 8	130	100	[12] 30 [12] 15	[12] 12 [12] 8	[6] 125 [7] 110	35	135
New York [23]	312	244	75	46	30	25	15	288	205	38	16	160	60	150
North Carolina [3]	220	170	65	40	35	22	16	200	144	35	10	120	70	150
North Dakota	250	[4] 250 [5] 200	[4] [12] 93. 75 [4] [12] 81. 25 [5] [12] 75 [5] [12] 65	[4] [12] 62. 5 [4] [12] 50 [5] [12] 50 [5] [12] 40	[4] [12] 50 [4] [12] 37. 5 [5] [12] 40 [5] [12] 30	[4] [12] 37. 5 [4] [12] 25 [5] [12] 30 [5] [12] 20	[4] [12] 32. 5 [4] [12] 20 [5] [12] 26 [5] [12] 16	[24] 234 [24] 195	150	30	12	150	50	200
Ohio [3]	225	175	60	35	30	20	15	200	150	30	10	125	25	125
Oklahoma [1]	250	200	60	35	30	20	15	175	150	30	10	100	100	200
Oregon [25]														
Pennsylvania [3]	[6] 215	175	60	35	30	20	15	[6] 215	150	40	16	150	----------	180
Puerto Rico [3]	[6] 300	[6] 200 [6] 180	75	40	30	25	15	[14] 175 [11] 300	[14] 175 [14] 160	30	15	[26]	50	200
Rhode Island [3]	[6] 300	199	60	36	26	20	18	[6] 300	150	30	10	120	60	150
South Carolina [1]	200	150	60	35	30	20	15	175	125	30	10	100	70	150
South Dakota [3]	[6] 200	150	50	35	30	20	15	[6] 160	125	30	10	150	----------	----------
Tennessee [3]	[6] 200	150	60	35	30	20	15	[6] 175	125	30	10	100	----------	150
Texas [1]	[6] 200	150	[12] 70 [12] 60	[12] 55 [12] 45	[12] 40 [12] 30	[12] 31 [12] 21	[12] 25 [12] 15	[6] 200	125	30	10	100	[27] 75	150
Utah [3]	200	150	[12] 60 [12] 30	[12] 30 [12] 20	[12] 30 [12] 15	[12] 20 [12] 12	[12] 12 [12] 9	[14] 180 [11] 150	125	[12] 30 [12] 15	[12] 12 [12] 6	[6] 120 [7] 100	50	200
Vermont [3]	[6] 170	140	40	25	20	15	10	[6] 170	120	20	8	100	[28] 42½	170
Virginia [1]	200	150	60	35	30	20	15	175	125	30	10	100	50	100
Washington [29]														
West Virginia [1]	[6] 240	200	80	40	28	20	20	[30] 240 [30] 200	140	40	16	132	----------	----------
Wisconsin [31]	500	400	[12] 125 [12] 100	[12] 60 [12] 50	[12] 45 [12] 35	[12] 26 [12] 20	[12] 28 [12] 22	[32] 500 [32] 425	250	[12] 83⅓ [12] 25	[33]	[6] 275 [7] 250	[34] 50 [34] 32	[34] 333⅓ [34] 180
Wyoming [35]														
United States:														
Federal employees [3]	[6] 312	244	75	46	30	25	15	[6] 288	205	38	16	160	52	200
Longshoremen [3]	[6] 312	244	75	46	30	25	15	[6] 288	205	38	16	160	52	200

[1] Payments under this schedule are in lieu of all other payments.
[2] Alaska: Law provides for payment of fixed sums for schedule injuries. For instance, for the loss of an arm or a leg, $7,200; for the loss of an eye, $5,600; for the loss of hearing in 1 ear, $1,500.
[3] Payments are in addition to payments for temporary total disability during all or part of the healing period.
[4] For major member.
[5] For minor member.
[6] By enucleation.
[7] Without enucleation.
[8] Loss at shoulder or elbow. In Minnesota and South Dakota amputation of arm below elbow considered loss of arm if artificial member cannot be used. In Maine, Mississippi, Tennessee, and under the Federal employees' act, loss of arm above the wrist shall be considered loss of arm.
[9] Loss of leg at hip or knee. In Maine, Mississippi, and Tennessee, and under the Federal employees' act, loss of leg above ankle considered as loss of leg.
[10] California: Ratings vary, based on age and occupation of employee. Figures given are standard ratings, prior to modification for occupation and age. The figures shown for arm, leg, and foot are for cases where reasonably satisfactory use of prostheses is not possible. Where prostheses can be used, the following figures apply: major arm, 280 weeks; minor arm, 260 weeks; major hand, 240 weeks; minor hand, 220 weeks; leg at or above knee, 260 weeks. In case of loss of an arm, or the major hand, or a leg, if reasonably satisfactory use of prostheses is not possible, after receiving benefits for the schedule period the employee is given a life pension of 10 to 20 percent of average weekly earnings.
[11] Loss of leg at or above knee if use of artificial limb possible.
[12] Loss of metacarpal bone in case of a thumb or finger, or metatarsal bone in case of a toe.
[13] Loss at proximal joint.
[14] Loss at hip joint, so close as to preclude use of artificial limb.
[15] Illinois: 235 weeks for loss of arm. If amputation is above elbow, 15 additional weeks is allowed. If arm is amputated so close to the shoulder joint that an artificial arm cannot be used, or if arm is disarticulated at the shoulder joint, an additional 65 weeks (a total of 300) is allowed. 200 weeks for loss of leg. If amputation is above knee, 25 additional weeks. If leg is amputated so close to hip joint that an artificial limb cannot be used, or if leg is disarticulated at the hip joint, an additional 75 weeks (a total of 275) is allowed.
[16] Indiana: Payments are in addition to payments for temporary total disability not exceeding 26 weeks, for partial or complete loss of member, 90 percent loss of vision in an eye, or complete loss of hearing in 1 or both ears. For other injuries, payments under this schedule are in lieu of all other payments.
[17] Indiana: For loss of 2d toe, 30 weeks; 3d toe, 20 weeks; 4th toe, 15 weeks; and 5th toe, 10 weeks.
[18] Kansas: Payments are in lieu of all other benefits, except that in certain cases additional compensation may be allowed during the healing period for not to exceed 10 percent of the schedule period, maximum 15 weeks.
[19] Maine: The incapacity is deemed to be total for the period given in the schedule. After the specified period, if there is actual partial or total incapacity, benefits for such incapacity shall be paid. (See Appendices E–15 and E–17.)
[20] Maine: Or for diplopia.
[21] Massachusetts: A flat sum of $20 weekly is payable for the specific periods listed. This is in addition to all other benefits. Loss or loss of use of fingers and toes is in proportion to loss of hand or foot.
[22] New Hampshire: Plus compensation for actual healing period not in excess of specified number of weeks, except in case of loss of hearing. Additional healing periods of some duration authorized (1) where loss of use subsequently results in loss by amputation or surgery, and (2) where there is loss to another member of which original was or is a component part.
[23] New York: In lieu of other payments unless period of temporary total disability exceeds fixed periods for each class of injury.
[24] North Dakota: Loss of leg at hip, 234 weeks; at knee, 195 weeks.
[25] Oregon: In addition to payments for temporary total disability, law provides for payment of $46.50 for each degree of injury. For instance, for loss by separation of 1 arm at or above elbow joint 192 degrees or $8,640; loss by separation of 1 leg above knee, 150 degrees or $6,750. There is no specific number of degrees set for loss of sight and hearing. These are figures on a proportionate basis to normal sight and hearing. (See Appendix E–15, footnote [14].)
[26] Puerto Rico: Permanent visual disabilities are to be determined by the manager of the State insurance fund.
[27] Texas: The Industrial Accident Board allows 75 weeks for loss of hearing in 1 ear.
[28] Vermont: In lieu of all other benefits except medical and hospital.
[29] Washington: Law provides for payment of fixed sums for specified injuries, which are in addition to payments for temporary total disability. For instance, for amputation of 1 leg so near the hip that artificial limb cannot be worn, $7,500; amputation of arm so near the shoulder that an artificial arm cannot be worn, $7,500; major arm at or above elbow, $6,375; loss of 1 eye by enucleation, $3,750; complete loss of hearing in both ears, $5,250.
[30] West Virginia: Loss of leg, 240 weeks; thigh, 200 weeks.
[31] Wisconsin: In addition to payments for temporary total disability. Periods during which payments are made for schedule injuries are based upon employee who is 50 years of age or less. Where employee is above 50, periods specified reduced by 2½ percent for each year the age of such employee exceeds 50.
[32] Wisconsin: Loss at hip joint, 500 weeks; at knee, 425 weeks.
[33] Wisconsin: For loss of 2d toe, 25 weeks, or 8 weeks for loss at proximal joint; other toes 20 weeks, or 6 weeks for loss at proximal joint.
[34] Wisconsin: For deafness due to accident or sudden trauma: 1 ear, 50 weeks; 2 ears, 333½ weeks. For total occupational deafness caused by exposure to noise in employment: 1 ear, 36 weeks; 2 ears, 180 weeks.
[35] Wyoming: In addition to payments for temporary total disability, law provides for payment of fixed sums for schedule injuries. For instance, for loss or arm above elbow, $4,800; for the loss of a leg above knee, $4,400; for loss of an eye or at least 90 percent of the sight thereof, $4,000. (No provision for loss of hearing.)

APPENDIX E–17

Minimum and maximum benefits for permanent total disability

State	Maximum percentage of wages	Maximum period	Payments per week		Total maximum stated in law
			Minimum	Maximum	
Alabama	[1] 55–65	400 weeks [2]	$5.00, or actual wage if less	$31.00	$12,400.
Alaska					$12,000–$15,000. [1]
Arizona	65	Life		$150.00	
Arkansas	65	450 weeks	$7.00	$35.00	$12,500.
California	[3] 61¾	400 weeks; thereafter 40 percent of average weekly earnings at time of injury, for life.	$15.00	$40.00	
Colorado	66⅔	Life	$10.00	$36.75	
Connecticut	60	Period of disability	$15.00	$45.00	
Delaware	66⅔	do	$18.00, or actual wage if less	$35.00	
District of Columbia	66⅔	do	$18.00, or average wage if less	$54.00 [3]	
Florida	60	do	$8.00, or actual wage if less	$35.00	
Georgia	60	400 weeks	$10.00, or actual wage if less	$30.00	$10,000.
Hawaii	66⅔	Period of disability	$18.00–$20.00 [1]	$75.00 [3]	(5).
Idaho	[1] 55–60	400 weeks; [4] thereafter $12 per week ($15 if dependent wife) for period of disability, plus $4–$15 for children.	$12.00–$30.00 [1]	$28.00–$48.00 [1]	
Illinois	[1] 75–97½	Life	$19.50–$33.00 [1]	$39.00–$45.00 [1]	(6).
Indiana	60	500 weeks (may be extended)	$18.00, or average wage if less	$36.00	$15,000.
Iowa	66⅔	500 weeks	$15.00, or actual wage if less	$32.00	
Kansas	60	416 weeks	$7.00	$34.00	
Kentucky	65	425 weeks [7]	$12.00	$32.00	$13,600.[7]
Louisiana	65	400 weeks	$10.00, or actual wage if less	$35.00	
Maine	66⅔	500 weeks	$15.00	$35.00	$14,000.
Maryland	66⅔	Continuation of disability [8]	$18.00, or average wage if less	$40.00	$20,000.
Massachusetts	66⅔	Period of disability [8]	$20.00	$40 plus $4 for each total dependent	
Michigan	66⅔	Period of disability [9]	$18.00–$28.00 [1]	$33.00–$57.00 [1]	
Minnesota	66⅔	Period of disability	$17.50, or actual wage if less	$45.00 [3]	(10).
Mississippi	66⅔	450 weeks	$10.00	$35.00	$12,500.
Missouri	66⅔	300 weeks, thereafter 40 percent of wages, maximum $27.50 for period of disability.	$16.00	$37.50	
Montana	[1] 50–66⅔	500 weeks	$25.50	$28.00–$42.50 [1]	
Nebraska	66⅔	300 weeks; [4] thereafter 45 percent of wages, maximum $27.50 for life.	$20.00 first 300 weeks; thereafter $17, or actual wage if less.	$34.00	
Nevada	[1] 65–90	Life	No statutory minimum	$34.50–$47.76 [1] [3a]	
New Hampshire	66⅔	341 weeks	$20.00, or actual wage if less	$37.00	$12,617.
New Jersey	(11)	450 weeks; [3] under certain conditions benefits paid for life.[12]	$10.00; after 450 weeks may be $5.00 [12]	$40.00 [12]	
New Mexico	60	550 weeks	$17.00, or actual wage if less	$30.00	
New York	66⅔	Life	$20.00, or actual wage if less	$45.00	
North Carolina	60	400 weeks; [3] 500 weeks for 2 injuries in same employment	$10.00	$35.00	$10,000.[3]

New Mexico	60	550 weeks	$17.00, or actual wage if less	$45.00	
New York	66⅔	Life	$20.00, or actual wage if less	$45.00	
North Carolina	60	400 weeks; [3] 500 weeks for 2 injuries in same employment.	$10.00	$35.00	$10,000.[9]
North Dakota	80	Life	$15.00, plus $2.80 for each dependent child under 18, but total not to exceed actual wage.	$31.50–$45.50 [1]	
Ohio	66⅔	do	$25.00, or average wage if less	$40.25	
Oklahoma	66⅔	500 weeks	$15.00, or actual wage if less	$30.00	
Oregon		Period of disability	Same as maximum	$25.38–$63.46 [1]	
Pennsylvania	66⅔	do	$25.00, or 90 percent of actual wage if less, but in no event less than $15.	$37.50	
Puerto Rico	60	540 weeks	$6.92	$13.85	$7,500.
Rhode Island	60	Period of disability [12]	$17.00	$32.00	(12).
South Carolina	60	500 weeks	$5.00	$35.00	$10,000.
South Dakota	55	300 weeks; thereafter 20 percent of earnings, maximum $15 for life.	$15.00, first 300 weeks; $12 thereafter	$30.00	$10,000.
Tennessee	65	550 weeks	$15.00, or average wage if less, but in no event less than $12.	$32.00	$11,000.
Texas	60	401 weeks	$9.00	$35.00	
Utah	60	260 weeks; thereafter 45 percent of wages during disability, maximum $35.[14]	$22.75–$30.71 [1]	$35.00–$47.25 [1]	(14).
Vermont	66⅔	330 weeks [4]	$18.00 or average wage if less	$30.00, plus $2 for each dependent child under 21.	$9,900.
Virginia	60	500 weeks	$6.00	$33.00	$13,200.
Washington		Life [2]	Same as maximum	$28.85–$56.77 [1]	
West Virginia	66⅔	Life	$20.00	$33.00	
Wisconsin	70	do	$14.00	$49.00 [2]	
Wyoming			$25.85–$32.31, plus $4.85 for each dependent child under 18.[1 15]	$25.85–$32.31, plus $4.85 for each dependent child under 18.[1 15]	$9,000–$15,350.[1 15]
United States:					
Federal employees	[1] 66⅔–75	Life	$25.96, or actual wage if less	$121.15 [2]	
Longshoremen	66⅔	Period of disability	$18.00, or average wage if less	$54.00 [2]	

[1] According to number of dependents. In Alaska, Idaho, Oregon, Washington, and Wyoming, according to marital status and number of dependents. In Massachusetts, the aggregate, including dependents' allowances, limited to average weekly wage.

[2] Additional benefits in specific cases, such as for vocational rehabilitation, constant attendant, paralysis from spinal injuries, or loss of mental faculties.

[3] The California law provides for 65 percent of 95 percent of actual earnings, or 61¾ percent.

[4] In case total disability begins after a period of partial disability, the period of partial disability shall be deducted from the weeks specified.

[5] Hawaii: After $25,000 has been paid, 50 percent of former rate to be paid from special fund, minimum $18 weekly.

[6] Illinois: After $10,750–$13,500, depending upon dependents, has been paid, annually thereafter 15 percent of the total previous payments in specific cases and 12 percent of such amounts in other cases of total and permanent disability is paid.

[7] Kentucky: If period of total disability begins after a period of partial disability, the period of partial disability shall be deducted from the 425 weeks, and the payments for partial disability shall be deducted from $13,600.

[8] Law expressly provides that such payments are in addition to payments for temporary total.

[9] Michigan: Law states that there is a conclusive presumption that disability does not extend beyond 800 weeks, but after that time the question of permanent total disability is determined in each case in accordance with the facts.

[10] Minnesota: After $18,000 paid, OASI benefits credited against workmen's compensation benefits.

[11] New Jersey: Benefits set in accordance with a "wage and compensation schedule."

[12] After 450 weeks, if worker has accepted such rehabilitation as may have been ordered by the Rehabilitation Commission, and such worker is unable to earn wages equal to wages before his accident, further benefits may be paid during disability, amounting to his previous weekly compensation payment diminished by the portion that the wages he is then able to earn bears to the wages received at the time of the accident. If his wages equal or exceed such former wages, his benefit rate shall be reduced to $5.00 a week.

[13] Rhode Island: After 1,000 weeks, or after payment of $16,000, payments to be made for life from second-injury fund.

[14] Utah: After payment of $14,116.71 by employer or carrier, a worker who cannot be rehabilitated receives from the combined injury fund 45 percent of wages, for period of disability, weekly maximum $35.

[15] Wyoming: As to the allowance for the children, the law states: "* * * there shall be credited to the account of each of such children * * * a lump sum equivalent to $21.00 per month ($4.85 per week) until the time when each of said children would become 18 years of age; provided that the lump sum credited to the account of all said children shall in no case exceed $6,350." The total maximum of $15,350 shown on the table includes the $6,350.

APPENDIX E–18

Minimum and maximum benefits for widows and children in death cases

State	Maximum percentage of wages		Maximum period	Payments per week		Total maximum stated in law
	Widow only	Widow plus children		Minimum	Maximum	
Alabama	35	65	300 weeks	$5.00, or actual wage if less	$31.00	$12,400.
Alaska						$9,000–$15,000.[1]
Arizona	35	66⅔	Widowhood, or to children until 18 or marriage.[2]	No statutory minimum	$80.77–$153.85 [1]	
Arkansas	35	65	450 weeks	$7.00	$35.00	$12,500.
California	[3] 61¾	[3] 61¾	250 weeks in cases of total dependency; 312.5 weeks in case of surviving widow and one or more dependent minor children.	$15.00	$50.00	$12,000–$15,000.[1]
Colorado	66⅔	66⅔	312 weeks	$10.00	$36.75	$11,466.
Connecticut	60	60	Widowhood, or to children until 18 [2]	$15.00	$45.00	
Delaware	50	80	400 weeks; thereafter to children until 18.	$15.00	$37.50–$60.00 [1]	
District of Columbia	35	66⅔	Widowhood, or to children until 18 [2]	$9.45, surviving spouse or dependent husband.	$28.35–$54.00 [1]	
Florida	35	60	350 weeks	$8.00, or actual wage if less	$35.00	
Georgia	51	51	400 weeks	$8.50, or 85 percent of actual wage if less	$25.50	
Hawaii	50	66⅔	Widowhood, or to children until 18 [2]	$15.00, widow or widower, or average wage if less.	$56.25–$75.00 [1]	$25,000.[4]
Idaho	45 [5]	55	400 weeks; thereafter to children until 18.[2]	$12.00–$15.00 [6]	$20.00–$30.00 [6]	$12,000.
Illinois	75 [7]	97½	Widowhood,[8] or children to 18 [2]	$19.50–$33.00 [1]	$39.00–$45.00 [1]	$10,750–$13,500.[1]
Indiana	60	60	400 weeks	$18.00, or average wage if less	$36.00	$15,000.
Iowa	66⅔	66⅔	300 weeks	$15.00, or actual wage if less	$32.00	
Kansas			Widowhood, or to children until 18 [2]	No statutory minimum in the case of partial dependents; no weekly minimum for total dependents but a minimum total of $2,500.	$34.00	$12,500.
Kentucky	65	65	400 weeks	$12.00	[9] $30.00	$12,000.
Louisiana	32½	65	do	$10.00, or actual wage if less	$35.00	
Maine	66⅔	66⅔	300 weeks	$15.00	$35.00	$10,500.
Maryland	66⅔	66⅔	500 weeks	$15.00, or average wage if less	$25.00	$10,000.
Massachusetts			400 weeks; thereafter to children until 18.[2]	$25.00, widow or widower	$25.00, plus $5 for each child	$10,000.[7]
Michigan	66⅔	66⅔	450 weeks	$18.00–$26.00 [1]	$33.00–$51.00 [1]	
Minnesota	40	66⅔	Widowhood, or to children until 18 [2]	$17.50, or actual wage if less	$45.00	$17,500.
Mississippi	35	66⅔	450 weeks	$10.00 [5]	$35.00 [5]	$12,500.
Missouri	66⅔	66⅔	Widowhood, or to children until 18 [2]	$16.00	$37.50	$12,000.

Montana	50	66⅔	500 weeks	$25.50	$28.00–$42.50 [1]	
Nebraska	66⅔	66⅔	325 weeks	$20.00, or actual wage if less	$34.00	
Nevada	50	80	Widowhood, or to children until 18 [2]	No statutory minimum	$23.08–$36.92 [1]	
New Hampshire	66⅔	66⅔	341 weeks	$20.00, or average wage if less	$37.00	$12,617.
New Jersey	35	60	350 weeks; thereafter to children until 18.	$10.00	$40.00	
New Mexico	40	60	550 weeks	$17.00	$30.00	
New York	40	66⅔	Widowhood, or to children until 18 [2]	$12.00–$20.00, surviving spouse	$27.00–$45.00	
North Carolina	60	60	350 weeks	$10.00	$35.00	$10,000.
North Dakota	45	75	Widowhood, or to children until 18	$13.50–$22.50 [1 3]	$18.00–$30.00 [1 3]	
Ohio	66⅔	66⅔	416 weeks	No statutory minimum	$40.25	$12,000.
Oklahoma						$13,500.
Oregon			Widowhood, or to children until 18 [2]	$20.77, surviving spouse, plus additional benefits for children.	$20.77–$48.46 [1]	
Pennsylvania	51	66⅔	350 weeks, thereafter reduced payments to children until 18.	$19.13	$23.75–$37.50 [1]	
Puerto Rico	60	60	540 weeks	$9.23	$17.31	$9,000.
Rhode Island	60	60	600 weeks	$16.00	$18.00, plus $2 for each child	
South Carolina	60	60	350 weeks	$5.00	$35.00	$10,000.
South Dakota	50	50				$7,500–$9,000.[4]
Tennessee	50	65	Widowhood, or to children until 18 [2]	$15.00, or actual wage if less, but in no event less than $12.	$32.00	$11,000.
Texas	60	60	360 weeks	$9.00	$35.00	
Utah	60	60	313 weeks	No statutory minimum	$35.00–$47.25 [1]	$10,266.70–$12,552.65.[1]
Vermont	40	50	330 weeks	$18.00	$30.00	$9,900.
Virginia	60	60	300 weeks	$6.00	$33.00	$9,900.
Washington			Widowhood, or to children until 18	$28.85, widow or invalid widower [5]	$28.85–$49.85 [1 5]	
West Virginia			Widowhood, or to children until 18 [2]	$15.00, dependent widow or invalid widower.	$15.00, plus $4.04 for each child; if child is an invalid, $4.61.	
Wisconsin	50	(7)	400 weeks	$10.00	$35.00 [8]	$14,000.
Wyoming			Widowhood, or to children until 18 [2]	$23.08, widow or invalid widower	$23.08, plus $4.85 for each child	$7,000–$13,350.[1]
United States:						
Federal employees	45	75	do	$15.58, widow or dependent widower	$121.15	
Longshoremen	35	66⅔	do	$9.45, surviving wife or dependent husband.	$28.35–$54.00 [1]	

[1] According to number of dependents.

[2] May be continued beyond age 18 if incapable of self-support. For Hawaii, see footnote 4.

[3] The California law provides for 65 percent of 95 percent of actual earnings, or 61¾ percent.

[4] Hawaii: However, the dollar maximum does not apply to children under 18; nor to unmarried children over 18 for 104 weeks beyond their 18th birthday, if they are incapable of self-support; nor to an unremarried widow who is physically or mentally incapable of self-support.

[5] Idaho: $12 minimum and $20 maximum if dependents are other than widow and children; $15 and $25 if widow only; $15 and $30 if widow with children.

[6] Illinois: Under certain circumstances, upon remarriage of childless widow remaining compensation payments shall be reduced by 50 percent.

[7] Additional benefits for dependent child; in Massachusetts, benefits continue to children until 18 or over 18 if incapacitated, and to widows during periods they are not fully self-supporting.

[8] In addition, lump-sum payment at death of worker. In Mississippi, $100 to widows; in North Dakota $300 to widow and $100 for each dependent child up to a maximum of $600; in Washington, $350.

[9] Wisconsin: Additional benefits payable from Children's Fund to the widow for children under 16 years of age (13 percent of the widow's benefit is the weekly or monthly allowance made for each dependent child), or for children over 16 if mentally or physically incapacitated.

APPENDIX E–19

Statutory provisions in the workmen's compensation laws relating to the rehabilitation of injured workers (these provisions are in addition to the provisions of the Federal Vocational Rehabilitation Act, which has been accepted by all the jurisdictions)

State	Maintenance and other benefits	Method of financing	Special provisions	Rehabilitation center
Alaska [1]	Maximum $50 a month for maintenance for permanently disabled persons. Total maximum $3,000 for "additional compensation, treatment, instruction, and necessary transportation." The Industrial Board is authorized to provide vocational rehabilitation by making cooperative arrangements with insurance carriers, private organizations, and government agencies.	From that portion of the second injury fund that exceeds $10,000.		
Arizona	The Industrial Commission is authorized to provide "such additional awards as may be necessary" for the promotion of vocational rehabilitation.	From a special fund, used in part for vocational rehabilitation. ($1,150 to be paid into such fund by employer in no dependency death cases. Also during any year, the Industrial Commission is authorized to direct payment into the State treasury, for this fund, of not more than 1 percent of premiums received by the State compensation fund.)		
Arkansas	Maximum $400 for training and incidental travel expenses for persons disabled from silicosis or asbestosis. Employee required to obtain approval of Commission before engaging again in a trade involving exposure to silicosis or asbestosis.	By employer		
District of Columbia	Maximum $25 a week for maintenance of permanently disabled persons during vocational rehabilitation as directed by the U.S. Secretary of Labor (in addition to compensation). Secretary of Labor may furnish prosthetic appliances or other apparatus.	Rehabilitation benefits, including prosthetic appliances and necessary services not available otherwise, payable from half of special fund financed by $1,000 payments in no dependency death cases, and fines and penalties collected.		

Florida			The Industrial Commission is directed to assist permanently disabled workers to obtain appropriate training, education, and employment, and is authorized to cooperate with the proper Federal, State, and other public or private agencies in the vocational rehabilitation of injured workers, and may pay for such services out of administrative funds. If the worker, without reasonable cause, refuses to undertake training, the Commission may suspend, reduce, or limit benefits.
Hawaii	The Director of Labor and Industrial Relations is authorized to make an expenditure up to $1,000 for any permanently disabled person for retraining and rehabilitation, including evaluation, instruction, necessary transportation, and maintenance.	Special compensation fund. ($2,000 paid to such fund by employers in each no-dependency death case.)	
Massachusetts	Insurers or self-insurers are required to furnish rehabilitation services by qualified physicians or facilities, and also to furnish vocational rehabilitation services to workers declared eligible by the Massachusetts Rehabilitation Commission. Such services include maintenance, transportation, training, guidance, and placement services, as well as "other goods and services necessary to render a handicapped person fit to engage in a remunerative occupation or in the occupation of homemaker."	By insurer	The Rehabilitation Commission is authorized to study the problems of rehabilitation for workers and other persons; establish and operate rehabilitation facilities and workshops; supervise small business enterprises established to be conducted by handicapped persons; enter into agreements with other agencies in connection with rehabilitation or placement of handicapped persons. The Rehabilitation Board is authorized to establish a list of physicians to render rehabilitation services for injured workers; appoint physicians as rehabilitation examiners for such workers; study problems of rehabilitation and examine rehabilitation facilities; and decide questions of rehabilitation payments by insurers or self-insurers.

[1] A special "Fishermen's Fund," financed by appropriations and by 30 percent of revenues from all commercial fishermen's licenses, provides medical care and assistance during convalescence to commercial fishermen not covered by workmen's compensation. The Board administering the fund is directed to provide treatment to rehabilitate the worker if possible and is authorized to cooperate with Territorial, State, Federal, and private agencies for this purpose.

34434—59——12

Statutory provisions in the workmen's compensation laws relating to the rehabilitation of injured workers (these provisions are in addition to the provisions of the Federal Vocational Rehabilitation Act, which has been accepted by all the jurisdictions)—Continued

State	Maintenance and other benefits	Method of financing	Special provisions	Rehabilitation center
Minnesota	66⅔ percent of wages, maximum $45 a week, not beyond 52 weeks (in addition to compensation).		Bureau of Workmen's Rehabilitation, under the control of the Division of Workmen's Compensation, is authorized to study each notice of injury incurred by a worker and if rehabilitation is indicated, inform the injured worker of available facilities and also notify the Division of Vocational Rehabilitation of the Department of Education. Also to keep a list of adequate facilities and personnel. Advisory Council of Rehabilitation authorized to advise on the administration and assist in developing adequate facilities and procedures.	
Mississippi	Maximum $10 a week, for not more than 52 weeks, for maintenance (in addition to compensation).		Commission to cooperate with rehabilitation agencies and to report cases of needed retraining.	
Missouri	Maximum $10 a week to injured employees while receiving physical rehabilitation. Period of such rehabilitation limited to 20 weeks except that the Board may, in unusual cases, extend the period for not more than an additional 20 weeks. Board may order employer to pay for transportation to rehabilitation facility.	From second-injury fund	Board of Rehabilitation, consisting of the Industrial Commission and the director of the Division of Workmen's Compensation, to study problems of rehabilitation, including methods through which rehabilitated workmen may be returned to employment without undue delay. Board also to certify rehabilitation facilities and doctors qualified to give rehabilitation services to injured workers; also to cooperate with the Department of Education and the Division of Employment Security in assisting rehabilitated workmen to secure suitable employment.	

New Jersey			Law specifies that after 450 weeks of receiving permanent total benefits ($40 weekly maximum), such compensation shall cease unless the employee shall have submitted to such rehabilitation as may have been ordered by the Rehabilitation Commission. [For future benefits in cases where workers have accepted such rehabilitation, see Appendix E–17.]	
New York	A worker totally or partially incapacitated, who is receiving rehabilitation, "may receive additional compensation necessary for his rehabilitation, not more than $30 per week of which may be expended for maintenance."	From special vocational rehabilitation fund. ($500 paid to such fund by employers in each no-dependency death case.)	The Labor Department authorized to cooperate with the Department of Education.	
North Dakota	Maximum $25 a week for 72 weeks payable for dependents during period of rehabilitation.	Workmen's compensation fund	Workmen's Compensation Bureau to cooperate with Federal vocational rehabilitation agency to obtain appropriate training, education, and employment for injured workers.	
Ohio	Maximum $20 a week for 52 weeks for maintenance, if authorized by Industrial Commission. Commission may also pay cost of artificial appliances.	$10,000 transferred semiannually from surplus insurance fund to vocational rehabilitation fund of State board for vocational rehabilitation, for maintenance payments and cost of artificial appliances.	Course of instruction must be undertaken within 60 days from date sufficiently recovered or as soon thereafter as Bureau of Vocational Rehabilitation shall provide opportunity.	State Rehabilitation Center (Ohio State University) authorized to restore, train, and reeducate, and place in productive employment physically handicapped workers. Industrial Commission authorized to make advance payments to the Center up to $50,000 each 3-month period as a credit for rehabilitation services for injured workers.
Oregon	From $50 a month if single, to $100 a month if married with 2 or more children, for retraining. Commission authorized to expend such funds as may be necessary to accomplish rehabilitation.	The State Industrial Accident Commission is authorized to set aside from the Industrial Accident Fund, and maintain a reserve in the amount of not less than $200,000 to be known as the Rehabilitation Reserve. Also 2½ percent of monthly receipts of the Commission from all sources. When unexpended balance of the rehabilitation fund is greater than $200,000, the monthly transfer is reduced or suspended.		Rehabilitation center established within the Industrial Accident Commission under the medical aid provision to make available to injured workers modern techniques for rehabilitation.

Statutory provisions in the workmen's compensation laws relating to the rehabilitation of injured workers (these provisions are in addition to the provisions of the Federal Vocational Rehabilitation Act, which has been accepted by all the jurisdictions)—Continued

State	Maintenance and other benefits	Method of financing	Special provisions	Rehabilitation center
Puerto Rico				Rehabilitation center established within the State fund under the medical aid provision to make available to injured workers the best in physical medicine and rehabilitation services.
Rhode Island		$750 in no-dependency death cases; 1 percent of gross premiums; penalties collected for any violation of the Workmen's Compensation Act except violation of the Second Injury Section.		Curative center established within Labor Department to make available to injured workers "all possible modern curative treatment and methods."
Utah	Maximum $700 for use in rehabilitation and training in permanent total disability cases and certain second injuries of a permanent partial nature arising from accidental injuries, as well as permanent partial and permanent total disability cases arising from occupational diseases. In addition, employees suffering from permanent partial disability arising from an occupational disease are granted $35 a week for not to exceed 10 weeks.	From a special fund, which is financed by payments of $2,566.67 in no-dependency death cases.	Where employee cooperates but cannot be rehabilitated, maximum $35 a week for life if permanently and totally disabled.	
Texas			Medical services to include treatments necessary for physical rehabilitation, including training in prosthetic devices. In addition, the Industrial Accident Board is to analyze each notice of injury and if rehabilitation is indicated, inform the injured worker of the facilities available to him under the Vocational Rehabilitation Division of the Texas Education Agency, and also notify the Division of such case.	
Washington				Rehabilitation center established within labor department under the medical aid provision to make available to injured workers the best in physical medicine and rehabilitation services.

West Virginia	Maximum $800 for each permanently disabled worker, plus temporary total payments for vocational training, including the use of crutches, artificial limbs, or other appliances or medical treatment as necessary. Each case to be authorized by the Commissioner.	Workmen's compensation fund		
Wisconsin	Actual and necessary maintenance and travel costs during maximum of 40 weeks of rehabilitation, if training provided elsewhere than at place of residence. Employer shall supply training in use of artificial members or appliances. (In addition to full compensation during training period, including rehabilitation period.)	By insurer	Course of instruction must be undertaken within 60 days from date sufficiently recovered or as soon thereafter as agency in charge provides opportunity.	
United States: Federal employees.	Maximum $50 a month for maintenance. Also provides for cost of rehabilitation services. (In addition to compensation.)	Appropriation of Congress	Where employee fails to undergo rehabilitation, the benefits may be reduced if the rehabilitation would have increased the employee's earnings.	
Longshoremen and harbor workers.	Maximum $25 a week for maintenance of permanently disabled persons during vocational rehabilitation as directed by the U.S. Secretary of Labor (in addition to compensation). Secretary of Labor may furnish prosthetic appliances or other apparatus.	Rehabilitation benefits, including prosthetic appliances and necessary services not available otherwise, payable from half of special fund financed by $1,000 payments in no-dependency death cases, and fines and penalties collected.		

CHAPTER 2. ASSOCIATED DOCUMENTS AND MATERIALS

PART I

RADIATION PROTECTION IN THE INDUSTRIAL USE OF RADIATION

PRESENTED AT SECOND GENEVA CONFERENCE ON PEACEFUL USES OF ATOMIC ENERGY, SEPTEMBER 6, 1958

By W. A. McAdams [1]

In the United States most information on radiation protection, and its effectiveness as measured by exposure and injury, has come from the Atomic Energy Commission and its prime contractors. Almost no information has been reported by private industry doing radiation work not under AEC contract. The record of private industry in such work is of considerable importance in evaluating the problems of health and safety in future expansion of the atomic energy industry.

The General Electric Co. is a typical U.S. corporation which has found it advantageous to use radiation and radioactive materials in many of its products and processes. At the present time, at least 72 departments of the company are engaged in radiation work of one kind or another. Since the company is highly diversified and decentralized, these separate departments operate almost independently of one another, and in many ways are like 72 different industrial firms. The plants involved are located in more than 40 cities spread through more than 20 States. The radiation work in these many installations includes the design and operation of nuclear reactors, the manufacture of X-ray and other radiation generating equipment, the use of radioactive materials in commercial products and manufacturing processes, research and engineering studies, activation analyses and quality control and testing of components and products. These facilities are believed to be a representative sample of the thousands in operation throughout the United States. This paper discusses the radiation protection programs and the record of personnel exposure within these private industrial plants. The paper does not give any data for facilities operated by General Electric for the Atomic Energy Commission.

RADIATION PROTECTION PROGRAMS

The type and amount of radiation protection required in any facility is dependent on many factors, one of the most important being the number of workers exposed, or having a potential for exposure, to radiation sources. Table I shows that about 22 percent of the industrial installations studied have less than 4 persons actually doing

[1] General Electric Co., Schenectady, N.Y.

radiation work and about 60 percent have no more than 10 such radiation workers. However, as shown in table II almost half of the installations have more than 40 persons working in the vicinity of radiation sources. Furthermore, if one considers that all persons employed in a plant have some chance for exposure it is apparent from table III that substantially larger numbers of employees are affected by the quality of the radiation protection program.

TABLE I.—*Number of radiation workers*

Number of workers:	Number of plants	Number of workers—Con.	Number of plants
<4	16	26–50	7
4–10	27	51–100	4
11–25	14	>100	4

Total radiation workers in all plants, 1,850.

TABLE II.—*Number of employees in vicinity of sources*

Number of workers:	Number of plants	Number of workers—Con	Number of plants
<10	15	101–200	7
10–40	23	201–500	5
41–100	19	>500	3

Total employees near sources in all plants, 6,430.

TABLE III.—*Number of employees per plant*

Number of employees:	Number of plants	Number of employees—Con.	Number of plants
<100	10	1,000–3,000	21
100–500	16	3,000–6,000	11
500–1,000	12	>6,000	2

Total employees in all plants, 112,000.

TABLE IV.—*Radiation protection personnel*

Number of specialists:	Number of plants	Number of specialists—Con.	Number of plants
None	3	1 man full time	6
Occasional help	30	More than 1 man	5
1–2 men part time	28		

Equivalent full-time specialists, 30.

Nearly all plants provide for radiation monitoring and inspection of sources, at least on a part-time basis. In some cases this service is furnished by an industrial hygienist or safety engineer who has had special radiation protection training. In other cases it is purchased from one of the several private companies that specialize in such work. Some of the departments rely on an equivalent service which is available on a charge basis from the general engineering laboratories of the company. Additional expert advice on radiation problems is also available from a full-time radiation protection consultant serving the company at large.

Table 4 shows the amount of specialized radiation protection assistance required for the 72 facilities studied. These figures indicate that the average radiation protection specialist serves about 60 radiation workers, and provides some protection for about 150 additional persons working in the vicinity of sources. On the average, only about 0.02 percent of the total work force or about 0.5 percent of the potentially exposed persons engaged in radiation protection work. As a

comparison, about 1.5 percent of the total work force in facilities owned by the Atomic Energy Commission are engaged in radiation protection work.

There are several reasons for the lower percentage of radiation protection specialists in private industrial facilities:

1. Most industrial users of radiation do not undertake any research or development work on radiation protection, but depend on the AEC and its contractors to supply them with information on new methods and techniques.
2. Nearly half of the industrial radiation installations are licensed by the AEC and rely heavily on the advice, regulations, and inspections provided by the AEC.
3. Some State agencies make periodic inspections of all industrial facilities and give special help on radiation hazards.
4. Many industrial users of radiation have only one or a few types of sources, and the radiation protection problems are not at all complicated.
5. Most industrial users purchase some services which are provided at AEC-owned facilities.

Nevertheless, in view of the exposure statistics which follow, it appears that industry has learned to operate broad radiation programs with a minimum of specialized protection personnel.

EXTERNAL EXPOSURE OF EMPLOYEES

The exposure of employees to external radiation is usually measured by conventional types of film badges supplied and processed by one or another of the 18 or 20 private film badge services available throughout the United States. In some facilities the film badges are supplemented by other personnel monitoring devices such as pocket ionization chambers. Some of the film badge services offer two or more varieties of film badges, each designed for a specific range of exposure conditions. Each installation selects the badge best suited to its exposure problems. In most plants, the film badges are worn for a period of 2 weeks or a month, but in a few cases an exchange period of 1 week is preferred. Many commercial film badge services report the minimum reading as zero, even though the least detectable exposure is actually 20 to 50 mrads. Most installations test the quality of the film badge service being used by exposing badges to known sources from time to time.

In plants where film badges are not used, the personnel exposure is estimated by monitoring the work areas periodically with dose-rate meters. In general, the facilities relying on this type of personnel monitoring have only permanently installed sources with well-established radiation exposure conditions.

Table V gives the average annual whole body exposure to penetrating radiations for three groups of employees. Group 1 includes all those persons actually working with radiation sources. Group 2 includes all of group 1 plus those working in areas where sources are present; i.e., those having a significant potential for exposure. Group 3 includes all employees of the plants covered. Wherever possible, the data in table V were averaged for a 5-year period. However, many of the plants have not been engaged in radiation work for that length of time and others have not maintained good exposure records for that period.

It should be noted that since many film badge services report minimum readings as zero, the averages in table V could be artificially low. However, this error has been at least partially offset by the fact that other services report minimum readings as less than 50, 30, or 20 mrads. In these cases the integrated individual recorded exposures are artificially high.

TABLE V.—*Whole body exposure*

Personnel group:	*Average annual exposure (rads)*
1	0.22
2	.062
3	.004

Over the periods for which exposure records are available, there have been 16 annual exposures of the whole body (or major portion) in excess of 3 rads. The two highest exposures were 12 and 40 roentgens, respectively. None of the high exposures produced any noticeable blood changes or other evidence of injury.

In order to compare the relative hazards of various types of radiation work, the average annual exposure was determined for several categories of radiation work. These data appear in table VI. It is seen that workers employed in manufacturing operations where radiation and radioactive materials are used receive somewhat higher exposures than persons doing other radiation work. In the manufacture of products this higher exposure is probably the result of longer exposure periods for the workers involved. In the process and quality control operations the higher exposures are probably due to the fact that the total exposure is spread over a relatively few people. In neither case is the exposure high enough to be of concern.

TABLE VI.—*Exposure received in typical kinds of work*

Type of radiation work	Number of plants	Average annual exposure (rads)	
		Group 1	Group 2
Manufacture of products containing radioactive materials	11	0.35	0.140
Process and quality control (not including radiography)	16	.34	.089
Industrial radiography and fluoroscopy	14	.28	.058
Use of X-ray diffraction equipment	14	.26	.110
Studies with radiation and radioactive materials	19	.23	.057
Manufacture and testing of radiation-producing equipment	21	.19	.055
Industrial medical uses of X-rays	19	.18	.043

PARTIAL BODY EXPOSURE

Many industrial radiation sources are mounted or shielded in such a way as to prevent exposure of the whole body. Yet exposure of the hands or some other part of the body is often possible. The film badge ordinarily will not give an adequate measurement of such partial body exposures. In this study it was found that very few plants have satisfactory procedures for determining the exposure received by parts of the body. This is due primarily to the fact that most available monitoring equipment is undependable or difficult to use for these measurements. Whatever the reason, it is apparent that there is insufficient data on partial body exposure to make a proper analysis of the situation.

This is most unfortunate, for the only radiation injuries reported in the 72 plants studied were the result of hand exposures. Three such injuries occurred during the last 5 years, all from the operation of X-ray equipment in the laboratory.

RADIOACTIVE CONTAMINATION

By and large, radioactive contamination has not seemed to be a serious industrial problem in most of the facilities investigated. There have been several cases of contamination spread to uncontrolled areas, but in no case has there been any evidence to show that the contamination was carried off the company premises. While about a third of the installations are using radioactive materials not in sealed-source form, only a few have more than a curie on hand at any one time.

In plants where large quantities of radioactive materials are handled, periodic urinalyses for specific radioactive isotopes are made on potentially exposed employees. Special urinalyses are scheduled in other plants following any untoward incident involving radioactive material. Nearly all plants have the urinalyses performed by some outside company specializing in such service, or by the General Engineering Laboratories of the company. The results to date indicate that no individual has acquired a body deposition of any radioactive material above a few percent of the maximum permissible limit.

RADIATION PROTECTION PROBLEMS OF SPECIAL INTEREST

The radiation work within the 72 facilities discussed in this report is extremely varied, but most of the protection problems encountered are similar to those which have been thoroughly described in the literature previously. However, a few manufacturing problems deserve special mention.

Manufacture of radiation generating equipment

The manufacture of X-ray and fluoroscopic equipment, particle accelerators, and radiation generating devices of all kinds, including radiation gages and teletherapy units, has to assume some responsibility for the radiation protection of his customers. This is ordinarily done by designing the equipment with special shielding and built-in safety mechanisms where this is feasible. Some manufacturers also assist their customers in the design and testing of the facilities where the equipment is to be used. In addition, they often give their customers special instructions about the radiation hazards involved in using the equipment. About two-thirds of the plants studied are using such radiation generating equipment and more than half of these reported that they had received some instructions from the manufacturer about the hazards.

Manufacture of high-voltage equipment producing X-rays

A number of the plants included in the study are engaged in the manufacture of products which produce X-radiation during their normal operation for other purposes. The production testing of such equipment must be carefully controlled and the potential hazards to customers must be taken into account. Kenetron, klystron, and other electronic power tubes, high-voltage rectifiers, oscilloscopes and flying spot scanners, are typical examples of such X-ray producing

equipment. The quality and quantity of the radiation produced in these products is, of course, dependent on the operating currents and voltages, but dose rates above 100 r/hr. and energies above 200 kilo electron volts are not unusual. Many of these devices are incorporated into other products such as radar sets and transformer assemblies, and, in order to protect the customer, special shields have to be provided around the X-ray-producing equipment itself or in the final assembly housing. As a further precaution, some manufacturers provide special instructions and attach warning notices to the equipment to call attention to the hazards.

Manufacture of television receivers

During the last few years much publicity has been given to the possible hazards of X-radiation generated in television receivers. The manufacturers have given considerable attention to this problem.

It is evident that soft X-rays will be produced in some of the cathode tubes used in television sets, but when the operating voltage is less than 20–25 kilovolts, the X-rays will be absorbed in the tube walls or in the surrounding case. As an approximation, the operating kilovoltage of the TV tube is equivalent to the diameter of the screen in inches. For example, a 17-inch tube would operate at about 17 kilovolts and a 21-inch tube would operate at about 21 kilovolts. Color TV sets are normally operated at higher voltages than black and white sets. Projection-type TV equipment is likely to be more hazardous because the sensitive screen is outside the tube. In this case the potential hazard can be twofold; that from the primary electron beam and that from the X-rays produced at the screen. The manufacturers have studied these problems thoroughly and have developed sets which are completely satisfactory from a hazards point of view. Nevertheless, the production testing of almost all types of television sets requires that rigid radiation-protection rules be enforced.

Manufacture of products containing radioactive materials

The U.S. Atomic Energy Commission is now able to supply quantities of many radioactive isotopes not previously available to private industry. As a result, manufacturers are now using these materials for a variety of new products, such as radioactive batteries, light sources, glow switches, and luminescent signs and markers. Also, manufacturers have found that the use of small amounts of radioactive materials in certain electron tubes, in the starter switches for fluorescent lamps and in many other products markedly improves their operating characteristics. These uses of radioactive materials can involve potential hazards to both the workers and the customers.

The several plants making such products have adopted a number of procedures which have reduced the radiation hazards to an acceptable level. By research and experimental techniques, the amount and kind of radioactive material are selected to give the optimum performance with the least possible exposure. For example, the radium used in luminous dial timepieces may soon be replaced with other radioactive isotopes which are much less hazardous, and which have a longer luminescent life and better light and color properties. In another plant, it was discovered that a smaller amount of a less hazardous radioisotope would permit further improvement in the properties of an electron tube. As a further protection to the customer, many of the plants surveyed are also labeling products that contain radioactive materials in amounts above established levels.

Conclusion

The experience of the General Electric Co. in 72 highly diversified and widely scattered operations is considered to be representative of the thousands of industrial plants now engaged in radiation work. The information reported for these 72 facilities indicates that industrial radiation hazards can be satisfactorily controlled and that a relatively small number of specialists are required to assure this control.

PART II

WORKMEN'S COMPENSATION AND RADIATION HAZARDS

STATEMENT BY DR. EARL F. CHEIT, PRESENTED TO THE AFL–CIO CONFERENCE FOR AFFILIATED UNIONS ON ATOMIC RADIATION HAZARDS, WASHINGTON, D.C., FEBRUARY 27–28, 1957

New industrial methods and materials are frequently accompanied by new job hazards—for example: enameling processes and the danger of lead poisoning; fluorescent lighting and beryllium-caused death and disease; increasing industrial uses of atomic energy and radiation injury and disease. As the industrial uses of atomic energy develop, the possibility that [more] workers will be exposed to disabling ionizing radiation makes urgent a reexamination of what protection is available to them.

In only 15 States (California, Connecticut, Indiana, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Washington, and Wisconsin) can we say with certainty that [such] cases will receive full coverage, unlimited medical benefits, and in general, the same protection offered all other injured workers. The other State laws offer combinations of uncertain coverage, limited medical benefits, and indefinite recovery.

Beyond the general weaknesses in the compensation protection of some States are others which have special significance for radiation cases. And unless many States make significant legislative changes, workers suffering radiation-caused disability will join a group of second-class beneficiaries under a system whose first-class citizens are not to be envied.

Basically, the radiation hazard of atomic energy is an occupational disease problem. Disability or death due to explosion or burn are clearly covered under all laws. But for those persons who escape death or immediate injury from atomic blast and who are subsequently afflicted, the problem of tracing disability to the accident and of gaining coverage may be more difficult. These persons, as well as those disabled from chronic exposure to ionizing radiations (a more significant group numerically), [will] likely encounter barriers to compensation for their disabilities.

Chronic exposure, either externally or through inhalation or ingestion, [may] cause injury or disease if it exceeds permissible safety limits. But, as experience with cases of tissue damage or ulcer from overexposure to X-rays or radium rays has taught, radiation-caused disease or injury may not develop its symptoms or create disability until months or even years after the harmful exposure.

Bone tumors suffered by young women working with radium dial paint in the 1920's were discovered as early as 2 years after exposure; yet new ones have been discovered as late as 1954, some 36 years after exposure.[1] Data from the [National] Cancer Institute, U.S. Public Health Service,[2] reveal that although the average latent period of occupational skin cancers due to X-radiation is 7 years, this period ranges from 1 to 12 years. Lung cancer from ionizing radiation has an average latent period of 25 to 30 years, and a latent period range of from 7 to 50 years.

Hopefully, there is much that can be done in the prevention of disability due to chronic exposure to ionizing radiation. With the aid of its labor advisory committee, and the published radiation protection standards of the Atomic Energy Commission, New York State has developed and put into effect a pioneering safety code for atomic radiation covering industry in that State.[3] Recommendations for legislative action in this field are available,[4] as are details for procedures, evaluation, and control of radiation hazards.[5] Even more encouraging, where such procedures and precautions have been used, safety records, such as those reported by the Atomic Energy Commission, have been very good.[6]

But sometimes exposures within permissible safety limits can later prove harmful. Industrial cases in which workers are not protected by safety standards must look to workmen's compensation laws for their economic rehabilitation. But they will find that disability due to occupational disease does not receive as good coverage or protection as does disability due to accidental injury under our compensation laws.

No one would seriously argue that a worker suffering bone destruction or a tumor due to chronic job exposure to radioactive material is less a casualty of industry than a coworker who loses a hand in a machine tool mishap, yet the compensation laws of many American jurisdictions will deny these workers equal treatment. There are three barriers to equal treatment: (1) failure to cover occupational disease; (2) time barriers to occupational disease claims; and (3) poorer medical benefits than those provided for the accidentally injured.

COVERAGE FAILURE

Two States, Wyoming and Mississippi, provide no workmen's compensation coverage for injury or death due to occupational disease. By contrast, full "blanket" coverage of all occupational disease is provided by 33 compensation laws.[7] The remaining 19 jurisdictions [8]

[1] "Proceedings of the Annual Convention of the International Association of Industrial Accident Boards and Commissions (IAIABC), 1955," Bureau of Labor Standards, Bull. 186, 1955 (p. 192).
[2] "Proceedings of the Annual Convention of the IAIABC, 1954," Bureau of Labor Standards, Bull. 180, 1954 (pp. 126–144).
[3] See "Monthly Labor Review" January 1956 (p. 62).
[4] "Proceedings of the Annual Convention of the IAIABC 1955" Bureau of Labor Standards Bull. 186, 1955 (pp. 195–198).
[5] Ibid. (pp. 180–186).
[6] "Proceedings of the Annual Convention of the IAIABC 1949" Bureau of Labor Standards Bull. 119, 1949 (p. 68).
[7] Alaska, Arkansas, California, Connecticut, Delaware, District of Columbia, Florida, Hawaii, Illinois, Indiana, Kentucky, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, Nevada, New Jersey, New York, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Utah, Virginia, Washington, West Virginia, Wisconsin, Federal Employees Compensation Act, and Longshoremen's and Harbor Workers' Compensation Act.
[8] Alabama, Arizona, Colorado, Georgia, Idaho, Iowa, Kansas, Louisiana, Maine, Montana, New Hampshire, New Mexico, North Carolina, Oklahoma, Puerto Rico, South Dakota, Tennessee, Texas, and Vermont.

offer the limited "schedule" type of coverage—that is, compensation only for certain stated diseases. The number of diseases covered ranges from 6 in Louisiana to 46 in Texas.

Experience under the laws of those States which have provided full coverage for some years seems to indicate quite clearly that (despite fears to the contrary) the costs of such coverage have actually proved to be remarkably small and have created no great problems of abuse or administration.[9] Even when a flood (of accrued liability cases) has been threated, such as in nontraumatic occupational loss of hearing, the provision of adequate protection has proved neither burdensome nor beyond administrative solution.

In defense of schedule coverage, it is sometimes maintained that a list of covered diseases can be fairly complete, without risking great sudden cost burdens to the compensation system. Quite aside from the fact that experience has proved such precaution unnecessary, it seems questionable compensation policy to ignore occupational disease and shift its cost to the workers rather than to the social insurance system which was created to assume and distribute it.

Schedules of occupational disease coverage tend to become inflexible; change is resisted; and even when schedules are revised, they very quickly become obsolete as the processes of work change. Most States with occupational disease schedules include radiation-caused disability. But after a study of these schedules, Ashley St. Clair, an official of a leading compensation insurance carrier, concluded that

> In a number of these laws, * * * the description used is so restrictive that some workers in those States who hereafter suffer radiation diseases as a result of work exposure to radioactive isotopes or to other forms of atomic energy will not be entitled to compensation benefits. In short, a schedule of compensable occupational diseases, even a schedule as complete as that of Texas, is an unsatisfactory device.[10]

We can readily agree with Mr. St. Clair's conclusion that there is no

> * * * good reason to give compensation benefits to one man suffering from an occupational disease and deny them to another, merely because the latter is suffering from a disease not known when the schedule was drawn.

But unless the occupational disease coverage is made general, that is precisely what may happen in radiation cases.

TIME BARRIERS

The statutes of limitations which many jurisdictions maintain are only slightly less serious in their effect of barring compensation for disability due to occupational diseases. In all States, a claim will be denied unless two notices are filed within a specified time after the disability. Although these requirements vary from State to State, the first notice, that to the employer, must be given usually within a month of injury; and the second, that for filing a claim, must be made within 1 year. Students of workmen's compensation seem agreed that the principle of a statute of limitations is justifiable. Without notice of claim, employers might be prejudiced. In addition, these bars tend to prevent easy abuse of benefits and reduce the possibility of a sudden flood of cases that could come from newly compensable

[9] Herman M. Somers and Anne R. Sommers, "Workmen's Compensation," New York, John Wiley & Sons, Inc., 1954 (pp. 50–53).

[10] "Proceedings of the Annual Convention of the IAIABC, 1949," Bureau of Labor Standards, Bull. 119, 1949 (p. 76).

hazards. And finally, to leave out a limitations statute makes it difficult if not impossible to write workmen's compensation insurance that is actually sound.

But a limitations statute can deny disabled workers benefits that are rightfully due them. This problem could be particularly acute in cases of radiation injury and diseases where the latent period may range as long as 50 years. Failure to give timely notice to the employer has in the past proved a minor problem since it has been easily excused. But for many jurisdictions, such a waiver is not likely under the second time limit—that for filing claims. In general, these statutes of limitations can be grouped into two types—those which run from the date of last exposure (or last day of work for the employer) and those which do not run until the date of disability. It is the former type of bar which, unless changed, will operate to preclude claims of many (perhaps most) radiation cases.

Eighteen [11] laws today bar compensation claims to workers whose disability occurs from 1 year to 5 years after exposure, with the most frequent period being 1 to 2 years.[12] Since the average latent period of skin cancers due to X-radiation is 7 years, and lung cancer about 30 years, the possible effect of these time bars in denying coverage is obvious. Those who change jobs, either within their company, or who take work elsewhere, and later develop radiation injury or disease may be barred from filing a compensation claim. They are neither entitled to idemnity, medical, nor rehabilitation benefits, although the causal relation to their employment would not be hard to identify. Furthermore, since their disability would be clearly occupationally caused, these workers could not benefit from group liability plans in effect today in many companies.

One approach, taken by a majority of American jurisdictions (to mitigate the effects of time barriers), is to specify a time bar which runs only from the date of disability, or from the time when the employee first found symptoms of the disease, or reasonably should have found them. Twenty-eight States [13] have such statutory provisions presently in effect. These time bars range from 60 days to 3 years.

This more flexible type of claims time limit was recommended by the U.S. Department of Labor "model bill." Section 28(a) (of that bill) provided:

> * * * the right to compensation for disability shall be barred unless a claim therefor is filed within 1 year after the injury or the manifestation of the disease claimed to have resulted from the employment * * * the time for filing claim shall not begin to run in cases of latent or undiscovered physical or mental impairment * * * until (1) the person claiming benefits knew, or by exercise of reasonable diligence should have known, of the existence of such impairment and its causal relationship to his employment and (2) he incurs loss of wages or has impaired capacity to earn * * *[14]

[11] Alabama, Arkansas, Delaware, Florida, Georgia, Hawaii, Idaho, Illinois, Iowa, Montana, Nebraska, North Carolina, North Dakota, Oregon, South Carolina, South Dakota, Vermont, and West Virginia.

[12] Only four jurisdictions have more than 2 years: Florida and Oregon, 3 years; and Delaware and Hawaii, 5 years.

[13] Arizona, California, Colorado, Connecticut, Indiana, Kansas, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nevada, New Jersey, New Mexico, New York, Ohio, Oklahoma, Pennsylvania, Rhode Island, Tennessee, Texas, Utah, Virginia, Washington, and Wisconsin.

[14] "Draft Provisions for a Comprehensive Workmen's Compensation Law," U.S. Department of Labor, November 1955 (p. 40).

Fortunately, the harsh effects of the statutes of limitations have been reduced through liberal court interpretation. Case law has in several jurisdictions stated that the time bar will not run until the disease is reasonably discernible,[15] or until the first manifestations of the disease, or until it is reasonably discernible that the disease is due to the employment. Although liberal court interpretation has brought many welcome changes to workmen's compensation laws, it is no substitute for adequate legislation.

MEDICAL BENEFITS

Some victims of radiation disease will be denied equal treatment with accidental injury cases because of the statutory limits on medical benefits for occupational disease. Like the occasional indemnity benefit limits found in the laws, most of these apply to silicosis and asbestosis cases only. Nevertheless, they are part of the larger problem of limits on medical benefits under compensation laws. Perhaps the easiest way, briefly, to examine the amount of medical care which radiation cases will receive under present-day workmen's compensation is to divide the laws into two groups. In the first group are those compensation laws which offer both full occupational disease coverage and unlimited medical benefits; in the second group are laws which limit either occupational disease coverage or medical benefits to the occupationally diseased, or both.

Twenty-five [16] of our 54 workmen's compensation jurisdictions [17] provide complete protection. Radiation cases, as well as all other occupational disease victims in these jurisdictions, will be assured of coverage as well as of unlimited medical benefits. Only one thing mars the admirable record of these 25 laws—7 of them also provide for time bars to recovery which run from last date of exposure (or employment). These are Delaware, Florida, Hawaii, Nebraska, North Dakota, Oregon, and South Carolina.

The second group—those that limit coverage and/or medical benefits to occupational disease cases—(is composed of 29 laws). Radiation disease victims in these jurisdictions will face a wide range of situations—most of them undesirable. First, in only seven of these laws—those offering full coverage of occupational disease—is it certain that radiation cases will be covered. Arkansas and Illinois provide radiation cases unlimited medical benefits (if claims are filed within 2 years and 1 year, (respectively), of last exposure). Alaska (for 4 years), and Nevada and Virginia (for 1 year), will cover these cases and provide full medical benefits. None of these laws has a time bar linked to exposure date alone. Utah covers all injuries and disease, and pays accidental injury cases unlimited medical benefits, but limits medical benefits to occupational disease cases at $1,600. West Virginia has a limit of $2,400 (plus a 2-year time bar after exposure).

[15] See William R. Schneider, "Workmen's Compensation Text," St. Louis, Thomas Law Book Co., 1943, vol. III (pp. 519–520).

[16] California, Connecticut, Delaware, District of Columbia, Florida, Hawaii, Indiana, Maryland, Massachusetts, Michigan, Minnesota, Missouri, Nebraska, New Jersey, New York, North Dakota, Ohio, Oregon, Pennsylvania, Rhode Island, South Carolina, Washington, Wisconsin, Federal Employees Compensation Act, and Longshoremen's and Harbor Workers' Compensation Act.

[17] 48 States, Alaska, District of Columbia, Hawaii, Puerto Rico, Federal Employees Compensation Act, and Longshoremen's and Harbor Workers' Compensation Act.

For the other 22 laws, a discussion of medical benefits for radiation cases is somewhat premature, since in many of these jurisdictions they will not be covered by the law. Mississippi and Wyoming make this certain by covering no occupational diseases—even though both States offer full medical benefits to the accidental injury cases that they do cover. But even if radiation disease coverage is somehow achieved in the other 20 laws, and time limits do not bar claims, only in 6 of these jurisdictions, will radiation cases get unlimited medical benefits: Idaho, Maine, New Hampshire, New Mexico, North Carolina, and Puerto Rico. In the other States, their benefits will range from $1,000 in Colorado to $2,500 in Iowa or full benefits for 91 days in Texas.

To anyone who has had experience with the treatment of radiation cases, the meaning of these limits on medical benefits is devastatingly clear. Treatment may require months, sometimes years, and often, many thousands of dollars. There has been an encouraging trend toward unlimited medical benefits, but until the remaining 17 jurisdictions [18] who limit them revise their laws, it is clear that radiation cases stand a poor chance of getting adequate medical care in these States.

SPECIAL PROBLEMS

Radiation cases raise other important workmen's compensation issues. Since radiation hazards are likely to produce cases with long latent periods, the question of how their liability should be apportioned between employers is bound to become an important one. So will the long-debated issue of the right to select a physician for medical care. Efficient administration of the specialized medical care needed for radiation cases may require a greater degree of supervision over medical care than now exists under our workmen's compensation laws. In fact, it is sometimes suggested that because of their somewhat unique nature these cases be given separate and special administration under the laws. Methods of insuring workmen's compensation liability may also be outmoded for this new hazard.

SUMMARY

Regardless of the level of this protection, radiation cases can be assured equal protection with victims of accidental injury when all States: (1) adopt full coverage of occupational diseases; (2) adopt flexible statutes of limitations on claims filings; (3) remove barriers to equal medical benefits; and (4) where they exist, remove other special requirements for occupational disease benefits.

EARL F. CHEIT, *St. Louis University.*

[18] Alabama, Alaska, Arizona, Colorado, Georgia, Iowa, Kansas, Kentucky, Louisiana, Nevada, South Dakota, Tennessee Texas, Utah, Vermont, Virginia, and West Virginia.

PART III

WHAT PROTECTION DO PRESENT-DAY WORKMEN'S COMPENSATION LAWS AFFORD WORKERS AND THEIR FAMILIES AGAINST WAGE LOSS FOR DISABILITY OR DEATH FROM OCCUPATIONAL DISEASE?

ADDRESS BY ASHLEY ST. CLAIR, COUNSEL, LIBERTY MUTUAL INSURANCE CO., BOSTON, MASS.—AT THE ANNUAL CONVENTION OF THE INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS, SEATTLE, WASH., SEPTEMBER 9, 1958

Mr. Bean, honored guests, ladies and gentlemen of the International Association of Industrial Accident Boards and Commissions, it is a privilege to speak to you men and women charged with the responsibility for administration of workmen's compensation laws in the United States and Canada. It is a great pleasure to be a guest here in the great Northwest, and particularly in Seattle, which, to me, is one of the two most attractive cities in the United States. In view of the excellent program arranged by your president, Mr. Kennedy, and your officers, and the outstanding hospitality extended by the State of Washington and others, each of us is fortunate to be here.

Perhaps I am more fortunate than most of you, because I have a daughter living here in the Northwest and my trip to Seattle has made it possible for me and Mrs. St. Clair to spend some time with her.

At your meeting in St. Louis in October 1949, I spoke to you about occupational disease problems. That paper analyzed the provisions of the various workmen's compensation laws with respect to occupational disease and point out that in many States workmen's compensation laws did not give workers and their families adequate protection against wage loss from occupational disease. It would be interesting to review the occupational-disease legislation enacted since 1949, but time does not permit. It seems better to summarize industrial and scientific developments since 1949, to state the problems created by occupational disease case emerging long after exposure, to state what protection State laws now give workers against occupational disease hazards, and to set forth what legislation is necessary to afford workers adequate protection against wage loss from occupational disease.

Since 1949 industrial research, particularly in the field of chemistry and physics, has proceeded at a constantly accelerating pace. New industrial processes in the field of chemical manufacturing have been developed. Many of these processes involve exposure to new disease hazards. The most dramatic and exciting developments in science and industry have been in the field of nuclear energy. To you,

radiation is not a new hazard. Many of you have processed radiation injury cases caused by exposure to X-ray or radium. Prior to 1946 the radiation hazard in private industry was confined almost entirely to X-ray installations, to the use of radium and its derivatives, to mining of radioactive ores, and to reactors and other nuclear facilities owned by the United States. In 1946, when most forms of nuclear energy were still a Federal Government monopoly, the Atomic Energy Commission started the distribution of radioisotopes for use in industrial processes, in research and in medicine. Today close to 5,000 [1] licensees of the Commission are using radioisotopes for these purposes. The Atomic Energy Act of 1954 ended for practical purposes, the Federal monopoly in nuclear energy and permits the operation by private business, research and educational institutions of almost every kind of nuclear facility. For many reasons, principally because of the substantial expense required for building nuclear facilities, the progress of private organizations in the nuclear energy field has not been as rapid as some persons hoped when the 1954 act was passed. Nevertheless, radiation exposure in private industry, in hospitals, in universities and in private research laboratories has increased many times in the past 10 years and will continue to increase. The comprehensive report filed last year by your Atomic Energy Committee, together with the exhibits attached to that report, make clear that there is a radiation hazard in industry in every one of States.[2] It is certain that that hazard has increased in almost every State during the past 12 months. Accurate information with respect to Canada was not available to me, but I know of industrial exposures in Ontario and Quebec and I suspect that Canadian industry, research and medicine are abreast of the United States in their uses of radioisotopes. It is certain, therefore, that the radiation injury problem is of increasing concern to everyone here today.

A number of persons have proposed that special and unusual measures are necessary to insure that workers injured by exposure to radiation get workmen's compensation benefits. These proposals are:

(1) that the problem is so complex that only the Federal Government can solve it and hence that the Federal Government should assume jurisdiction over radiation injuries suffered by employees of Government contractors and of Atomic Energy Commission licensees;

(2) that a person suffering a radiation injury or who has been exposed to excessive amounts of radiation without symptom of injury receive special compensation benefits beyond those afforded workers suffering injuries from other causes;

(3) that whatever compensation law may be applicable, that law should contain provisions necessary to make certain that a worker suffering from a serious radiation injury receives the special medical treatment required in such a case;

(4) that because radiation injury may not manifest itself until many years after exposure, every compensation law applicable to radiation injury should contain a special statute of limitations applicable only to that injury.

[1] Release No. 948, U.S. Atomic Energy Commission, Dec. 31, 1956.
[2] Report of IAIABC Atomic Energy Committee for 1957, Hon. Clay Shackelford, chairman, p. 65, IAIABC proceedings—1957, Bulletin 195, U.S. Department of Labor.

None of us will quarrel with the objective these persons are seeking to accomplish, namely to make certain that a worker who suffers a radiation injury gets adequate compensation benefits, including such medical treatment as he requires. The remedies they propose, however, are in some respects too drastic and in other respects too narrow.

It is not necessary to advisable to give the Federal Government jurisdiction over claims for radiation injury suffered by a limited class of workers. The compensation laws of a number of States already afford an adequate remedy for radiation injury.[3] In my own State of Massachusetts, a worker who suffers such an injury, even if it does not emerge until 20 years after exposure, is entitled to compensation benefits, including whatever medical and hospital care he may require during his lifetime. There is no good reason why a man who receives a radiation injury should receive compensation benefits in excess of those given another man who suffers an equally disabling injury from trauma or disease. To the extent that any compensation law does not assure skilled medical and hospital care to a worker who suffers serious injury, that defect should be cured. To the extent that any compensation law does not afford an adequate remedy for any occupational disease, that law should be amended, and the amendment should not be restricted to radiation injury, but rather should include every occupational disease.

Two effects of exposure of man to radiation deserve mention here, because they raise unusual problems in handling workmen's compensation claims. First, the effect of repeated exposure to small amounts of radiation, each one of which may be within the so-called permissible dose, is cumulative with the result that such repeated exposure may cause disability. Second, a radiation injury may not become manifest until many years after exposure. These effects, however, disabling injury after long-repeated exposure and long-delayed emergence after exposure, are not peculiar to radiation injury or novel to you. Silicosis is perhaps the most common, and certainly the best known, of those diseases which result from repeated exposures over a period of time to a harmful substance. Long-delayed disablement after exposure to compressed air, arsenic, benzol, beryllium, cadmium, chrome, fluorine, and other metals and chemicals is common. Any occupational disease caused by repeated exposures to an injurious condition and whose emergence may be long delayed after exposure, presents problems similar to those posed by radiation injury. These problems should be kept in mind as we turn to an analysis of the occupational disease provisions of our workmen's compensation laws and what changes in those laws are necessary to secure workmen's compensation benefits to workers suffering from occupational disease.

In each of six general areas legislative action is necessary in some jurisdictions to bring the occupational disease provisions of all of our workmen's compensation laws to the standard required by a modern industrial society.

1. In view of present-day disease hazards in industry, and particularly of the increasing radiation hazard, should not every jurisdiction make compensable, under a proper definition, every occupational disease?

[3] California, Florida, Kentucky, Louisiana, Massachusetts, Michigan, Missouri, New York, Rhode Island, Tennessee, Virginia, and Washington.

2. Should not whatever time limitation is applicable to an occupational disease claim run from the date of disablement or other positive manifestation of disease?

3. Should not the last of several successive insurers of the same employer be liable for all of the compensation due for an occupational disease caused by long-continued exposure during the successive periods of coverage?

4. In a case where it is established that an occupational disease is due to exposure in the employment of several successive employers, should liability for compensation be prorated against each such employer, or should the employer in whose service the claimant was last injuriously exposed be solely liable for all compensation due?

5. Should not all of our workmen's compensation laws provide medical benefits for the time and in the amount necessary to provide the medical and hospital care necessary in radiation injury and other serious occupational disease cases?

6. Should the law of each of our workmen's compensation jurisdictions and regulations made pursuant to that law require an employer with a radiation hazard to observe proper safety precautions and to keep an accurate record of what employees are exposed to radiation, to preserve badges, films, and other information necessary for the safety of his employees and for the orderly handling of claims for compensation on account of radiation injury?

Only the last of the problems above stated is peculiar to the use of nuclear energy by private organizations. The dramatic development of nuclear fission, including the bomb, during the past few years, with attendant publicity, should not blind us to, but rather should serve to highlight, the fact that a defect in a workmen's compensation law, such as an unfair and unrealistic limitation of the time within which after exposure a disease must emerge to be compensable, will probably bar recovery in many more industrial poisoning than radiation cases. While we are considering the problems of those few thousand workers exposed to radiation as they go about their daily tasks, let us not forget the hundreds of thousands of persons who are exposed every working day to industrial poisons and harmful dusts.

In only 32 U.S. jurisdictions are all occupational diseases compensable. In one of those jurisdictions there is a separate occupational disease law which the employer is presumed to accept unless he affirmatively rejects it. In two States an affirmative election by an employer is necessary if he wishes to provide workmen's compensation benefits for his employees who may suffer occupational disease. In one State, Virginia, the law permits an employer to reject complete coverage for occupational disease and elect to be liable only for the diseases listed in a schedule. In each of 19 U.S. jurisdictions only those occupational diseases listed in a schedule are compensable. In one of these States, Tennessee, the compensation law provides benefits for a limited number of diseases specified in a schedule, and to provide complete protection the employer once again must so affirmatively elect. These schedules run from one extreme to the other. Texas lists 46 diseases. Alabama, at the other end, lists only occupational pneumonoconiosis. Most of these schedules include a

definition designed, it is to be presumed, to include all forms of radiation injury known when the schedule was drawn. Only one of the definitions, however, can be construed to cover all forms of radiation injury. For instance, Arizona's definition, "ulceration of skin or destruction of tissue due to roentgen rays or radium emanations," does not include injury caused by any of the hazards created by nuclear reactors. The Texas definition, "diseased condition caused by exposure to X-rays or radioactive substances," does not include radiation injury from a particle accelerator or an electronic device, such as radar. Maine's schedule does not include any form of radiation injury.

Three States, Mississippi, Montana, and Wyoming, still afford no workmen's compensation benefits for occupational disease.

Today the United States is the leading industrial nation in the world. Only a few States are still predominantly agricultural. Within the lifetime of many of those present here, States like North Carolina, Louisiana, Texas, and Missouri have changed their economies from predominantly agricultural to predominantly industrial. Other States, like South Carolina, Georgia, Alabama, and Tennessee are treading on their heels. In the light of today's conditions and of the future which is close upon us, a future involving widespread use of nuclear energy for power and other purposes, of still more complex industrial and chemical manufacturing processes, every one of our compensation jurisdictions should make every occupational disease compensable. This objective should be accomplished by providing that disablement from an occupational disease, under a comprehensive definition, is compensable in the same manner as an injury by accident. The schedule device, however comprehensive, is unsatisfactory because today's schedule will not include tomorrow's disease. To repeat what I said to you in 1949, there is no good reason to give compensation benefits to one man suffering from an occupational disease and deny them to another, merely because the latter is suffering from a disease not known when the schedule was drawn.

Next, should a compensation law contain a provision that to be compensable disablement from an occupational disease must occur within a short period after the last exposure or after the last day of work for the employer from whom compensation is claimed? Thirty jurisdictions have such a provision in their compensation laws. The period of limitation after exposure varies from 120 days to 5 years. Consider a case of lung cancer from chrome developing 4 years after the victim left his employment in which he was exposed to chrome. In 25 jurisdictions in which occupational diseases are supposed to be compensable, that unfortunate man would never acquire a right to compensation for a statute of limitations to run against. The same principle applies to a delayed emergence radiation injury and to other occupational diseases. Is there now any good reason to deny compensation in such a case merely because the claimant's disability does not occur within a specified period after exposure or employment? Such time limitations should either be dropped altogether or made sufficiently long so that only occasional and unusual cases will be barred. There is ample experience to establish that the removal of such a limitation will not result in placing an undue burden on industry. A number of leading industrial States have no such limi-

tation.[4] The accumulated experience of employers and carriers in these States proves that it is feasible for every State either to drop such a limitation altogether or to extend it to, say, 20 years.

One of the most difficult problems facing a compensation administrator in deciding a case of disease resulting from repeated exposure over a long period of time is the proration of liability between successive carriers of the same employers or between successive employers of the injured claimant. The investigation and litigation of such cases is long and expensive. For that reason the private workmen's compensation carriers, through the cooperation of the National Council on Compensation Insurance and other workmen's compensation insurance rating bureaus, included in the new standard provisions workmen's compensation and employers' liability policy, put into use in 1954, a provision that as between several successive insurers of the same employer, the insurance carrier on the risk on the last day of the last injurious exposure to conditions causing a disease is liable for all of the compensation due the claimant from that employer. This provision, in force only 4 years, has worked very well and over the years will serve to reduce the cost to the carriers of processing occupational disease claims. Each of our compensation laws should provide that the last of several successive employers of a claimant suffering from an occupational disease caused by an injurious exposure in each such employment be solely liable for all of the compensation due the claimant. Several occupational disease laws contain such a provision, subject to the qualification that in cases of silicosis or asbestosis an exposure of less than 60 days shall not be deemed a last exposure. A comparable provision is necessary for radiation cases. In a number of States, however, proration between employers is provided by law. Once again, the cost of investigating and litigating such cases is excessive. To make the last employer solely liable for all of the compensation benefits due the claimant would save time of compensation administrators and would save time and expense for employers and their insurance carriers.

A workmen's compensation law has two prime objectives. The first is to provide weekly benefits in lieu of wages lost because of disability from a work injury. The second, and of equal importance, is to cure or relieve a workman of the effects of that injury and to restore his work ability as promptly as possible. Weekly compensation benefits are not within the scope of this paper. Let us turn, therefore, to the question of whether today's workmen's compensation laws afford adequate medical benefits for occupational disease cases. Our Federal workmen's compensation laws, and 34 of our State laws, give complete medical protection for traumatic injuries. Of those 34 States, a number limit such benefits payable in some or all occupational disease cases.[5] Fourteen of our States and Alaska limit either the period during which medical payments are payable or the total amount payable in each compensation case. Of these, seven States apply both limitations. Of these 15 jurisdictions the largest benefit payable is $2,500, the lowest $1,000. The shortest period during which medical benefits are payable is 120 days; the longest is Alaska's 4 years with no dollar limitation. That the most generous of these limited benefits is inadequate goes without saying. Many

[4] See exhibit D.
[5] See exhibit F.

occupational disease cases require months and even years of treatment. Within my own experience I have seen a radiation burn case still under treatment 17 years after the injury first manifested itself. A case of tuberculosis following silicosis may require long hospitalization. Medical treatment of aplastic anemia from benzol poisoning is expensive. It is not necessary to add to that list because all of you have seen many long-drawn-out disease cases requiring months and years of treatment. Further, some workers who have suffered from occupational disease are as much in need of rehabilitation as a man who has lost an arm or a leg. A foundry worker suffering from silicosis and unable to return to his dusty trade but able to work should be given the opportunity and means to learn another occupation. A reactor employee who has suffered more than the maximal permissible dose of radiation should likewise be given the means and opportunity to learn another trade.

The aggregate number of compensation cases, countrywide, requiring long-drawn-out, expensive medical and hospital care is large. Relatively, however, such cases are few in number. The experience of those States, including our most heavily industrial States, which provide full medical benefits, establishes that such full benefits do not impose a heavy burden on employers and carriers. On the contrary, the additional cost of providing such benefits is only a small percentage of workmen's compensation premiums.[6] Our industrial society can no longer refuse to provide the medical and hospital care necessary for the treatment of every victim of our industrial processes. Further, there is no sound reason to discriminate, with respect to medical care, against persons suffering from occupational disease.

Let us now turn briefly to two problems peculiar to the radiation hazard. That exposure to radiation causes genetic injury is well established. That injury may be roughly described as an alteration in the complicated chemical nature of one or more of a person's genes. This alteration, called a mutation, ordinarily affects each gene independently and, once changed, an altered gene then persists from generation to generation in its new or mutant form. Any radiation dose, however small, can induce some mutation. There is no minimum amount of radiation dose which must be exceeded before any mutations occur. Every living thing, fruitfly, corn plant, mouse or man, suffers mutations which arise from natural causes, cosmic rays, radiation from radium and similar substances in rocks and in soil, and from heat and certain chemicals. These unavoidable mutations are called spontaneous mutations. Additional radiation, as from an X-ray, produces mutations additional to the spontaneous mutations. These mutations, all of them, affect those hereditary traits which a person passes on to his descendants. Such a result will occur, even though the ancestor, during his lifetime, never exhibits any evidence of injury.

Some persons have urged that workers exposed to radiation receive workmen's compensation benefits for genetic injury. I submit that this proposal is unsound. The ultimate and only sufferer from a radiation injury to a gene is not the ancestor who was irradiated, but one of his descendants, and probably a remote descendant. To

[6] Illustrative of the small cost of providing adequate medical coverage, the manual rate in Kentucky for additional medical coverage, $100,000 for each injured person is 2.0 percent of the manual premium; in Kansas, 1.5 percent; in Alabama, 4.5 percent; in Colorado, 4.5 percent; in Georgia, 3.5 percent; in Iowa, 3.5 percent. Charges in other limited-medical coverage States are within the range indicated above.

pay indemnity because of genetic injury, the extent and result of which is impossible ever to establish, to a person who has been exposed to radiation is to pay that indemnity, not to the person actually injured, but to another person. If, in fact, the increasing exposure to radiation of our population causes an increase in the number of children born with serious physical and mental defects, it is the duty of our society to care for those unfortunate persons rather than to indemnify their ancestors.

Probably the most important task facing us in the atomic age is to make certain that every precaution necessary to prevent radiation injury to the public and to workers exposed to radiation sources is taken. The Atomic Energy Commission promulgated its safety regulations, effective January 16, 1957.[7] The standards so established agree substantially with those recommended by the National Committee on Radiation Protection and included in the model regulations suggested by that Committee and adopted by some States.[8] It must be noted, however, that the Atomic Energy Commission regulations apply only to persons who are licensed by the Commission to receive, possess, use, or transport nuclear materials and do not apply to persons using radium or radon, X-ray machines, particle accelerators or radar, each of which carries a substantial radiation hazard. Further, the Commission regulations do not apply to the mining, refining, or milling of radicative ores. It follows that although the Atomic Energy Commission by its safety regulations has preempted the field with respect to its licensees, State regulation of radiation sources is vitally necessary. Every State should adopt a radiation safety code, preferably the model regulations recommended by the National Committee on Radiation Protection. Not only is it desirable that safety regulations be uniform from State to State, but, because the National Committee on Radiation Protection is continuing its studies of how to limit and control radiation hazards and will publish from time to time amendments and additions to its model regulations, each State which adopts such regulations can, with little expense, keep abreast of developments in this fast expanding field.

Safety regulations, however adequate, are useless unless enforced by civil authority and observed by those persons and organizations making use of nuclear energy. At this point a State wishing to control radiation hazards within its borders faces several difficult problems. If those hazards are substantial, effective control will require a number of trained personnel. Most of the radiation hazard in the State may be created by Atomic Energy Commission licensees or contractors who are subject to Commission regulations. That fact need not deprive a State of a significant role in controlling radiation hazards. With respect to Atomic Energy Commission licensees, however, the State must be willing to act as an agent of the Federal Government and to assume responsibility for enforcement of Atomic Energy Commission regulations. Every State has one or more agencies which inspect working conditions in industrial plants, the discharge or disposal of industrial wastes, and other hazards affecting the health and safety of its citizens. Such a State agency, if it has a sufficient number of personnel trained in radiation hazards, can, by appropriate

[7] "Atomic Energy Commission Safety Regulations," pt. 20 (22 F.R. 548).
[8] "National Bureau of Standards Handbook No. 61," available from Superintendent of Documents, U.S. Government, Washington, D.C.

agreement with the Atomic Energy Commission, undertake the enforcement within that State of Commission regulations with respect to all or a part of Commission licensees in the State. This procedure is authorized by the 1954 act.[9] That the Commission intends to use to the full the authority given it by this provision, and even to expand further the role of the States in enforcing the safety standards set by Commission regulations, was made clear by Mr. Harold L. Price, Director, Division of Licensing and Regulation, Atomic Energy Commission, in a paper given March 26, 1958, before the President's Conference on Industrial Safety. Full cooperation in this area between the Atomic Energy Commission and the States will eliminate unnecessary duplication of effort, save money, relieve Atomic Energy Commission officials and inspectors for work in other areas and come close to achieving throughout the country effective protection against radiation hazards.[10]

The effectiveness of radiation protection regulations, even though zealously enforced, will depend upon the cooperation with State and Federal authorities of the managements of those organizations using radiation sources. In each laboratory, hospital and industrial plant, with a radiation hazard strict safety procedures must be followed. There must be continuing education of every exposed employee to make certain that he understands the procedures he must follow for his own safety, for the safety of his fellow workers and for the protection of the public. Management must make certain by constant strict supervision that the prescribed safety procedures are followed. From experience we know that familiarity breeds contempt, that lax supervision and low standards breed lax work habits and careless practices. In short, to paraphrase a well-known saying, eternal vigilance is the price of safety.

It is beyond the scope of this paper to recite those safety standards to be observed under various conditions. However, there are two sections of the recommended regulations of such importance to the orderly handling of radiation injury claims that they deserve brief mention here. Of those questions which have engaged the attention of lawyers who have studied the various legal problems arising from the widespread use of nuclear energy, one of the most perplexing is that of proof. How will a worker who has been exposed to radiation and who is suffering from a disease possibly caused by radiation ascertain the amount of radiation to which he has been exposed? How will an employer against whom such a claim is made get evidence, if he believes the claim unfounded, to defend it? Two sections of the model regulations, primarily directed toward the safety of persons working in the vicinity of radiation-producing sources, are nevertheless of prime importance to those who will be engaged in the handling of alleged radiation injury compensation claims. Section 8, dealing with personnel monitoring and radiation surveys, is intended not only to protect workers against radiation, but also to establish the amount of radiation to which a worker has been exposed. Section 9 prescribes the radiation exposure records which must be kept of all of the meas-

[9] Atomic Energy Act of 1954, sec. 161(f), 68 Stat. 948, 42 U.S.C.A. sec. 2201(f) (Supp. 1954) providing that the Commission may "* * * with the consent of the agency concerned, utilize or employ the services * * * of any Government agency or any State or local government, or voluntary or uncompensated personnel, to perform such functions on its behalf as may appear desirable."

[10] For a comprehensive discussion of the problems of State and Federal cooperation in this field, see Krebs and Hamilton, "The Role of the States in Atomic Development," 21 Law and Contemporary Problems 182, 196-204 (1956).

urements required under section 8. From these records, if properly kept and preserved by a Commission licensee or other employer with a radiation hazard, it will be possible to determine whether an individual has been in the vicinity of a radiation-producing source, and, if so, the approximate amount of radiation to which he has been exposed. Because persons skilled in the nuclear arts, as well as many other workers, will in the course of their working lives work at a number of nuclear facilities, it is imperative that these records be kept, that they be accurate, and that they be preserved. Moreover, because of the mobility of nuclear workers, it is desirable that such records be uniform throughout the country and even throughout the world. The importance of these records, first from a safety standpoint and second for use by both plaintiffs and defendants in claimed radiation injury cases, is so obvious that the point need not be labored further. One of the chief tasks of those civil authorities charged with enforcing radiation safety regulations is to see that the records required by applicable regulations are kept and preserved.

Atomic Energy Commission installations, whether operated directly by the Commission or by Commission contractors, have a remarkable safety record. Only a few persons have suffered radiation injury from exposure at or from such installations. The Commission, which admittedly has almost unlimited funds at its disposal and which does not have to operate at a profit, has spared no expense to create safe working conditions, to establish adequate safety procedures and to see that those procedures are carried out. A private business or research organization, faced with the necessity of operating on a limited budget, may well be tempted to skimp, in one way or another, on the necessary safety measures and procedures. Purely from the standpoint of dollars and cents, no private organization can afford to give in to that temptation. The cost of carelessness in dealing with radiation sources is greater than the cost of safety.

Since the close of the war in 1945 much has been done to improve the lot of a worker who suffers an occupational disease. A study of the exhibits attached to the copies of this paper available for distribution makes clear that much remains to be done before a workman suffering from an occupational disease has, in every jurisdiction, the plain, sure, speedy remedy available to one who has suffered a traumatic injury. Exhibits A, B, and C show that legislation by 20 States is necessary to make every occupational disease compensable in all of our compensation jurisdictions. Exhibits D and E show that legislation by 29 States is required to remove from their workmen's compensation laws unrealistic limitations on the time within which an occupational disease must become manifest to be compensable. Exhibit F shows that legislation by 23 jurisdictions is necessary to provide, in every U.S. compensation jurisdiction, medical benefits sufficient to cure and relieve and restore to work ability a workman suffering from a serious occupational disease. Exhibit G shows that 41 States have yet to adopt modern radiation safety codes. To one not familiar with the occupational disease legislation of the last 25 years, the task outlined above seems indeed herculean and perhaps impossible of accomplishment.

To one familiar with the progress made by State legislation in the occupational disease field in the last 25 years, the task before us seems almost easy. As late as 1936 the laws of only 16 of our States provided compensation benefits for occupational disease. Of these, seven had a restricted schedule. Of those schedules three did not include any radiation injury. Today the compensation laws of 45 States include provisions for occupational disease. Of those 45, 28 make every occupational disease compensable. To those of us who believe that occupational disease problems will and can be best solved by action by the States, the accomplishments of the last 25 years are an earnest for the future and should encourage those interested to redouble their efforts to secure appropriate State action where necessary.

It is also urged that the increasing use of nuclear energy by private industry has created an emergency which must be dealt with immediately and that immediate action can be secured only by resort to the Federal Congress. I submit there is no such emergency. In every jurisdiction an injury caused by an exposure to an excessive amount of radiation will be apparent within a short time and will be regarded as an injury by accident and hence compensable. It will be several years at least before delayed emergency injuries from today's exposures present a problem. There is ample time for careful and intelligent study by those interested of the problems arising from the increasing use of nuclear energy, and for appropriate action by State legislatures. The desired objectives can be attained by intelligent cooperation between each State government, its private industry, insurance carriers including State compensation funds, compensation administrators and labor, and this without turning over to the Federal Government still another segment of the powers of our several States. I will, however, sound a note of warning. These objectives cannot and will not be attained by State action unless every agency interested, public and private, recognizes and meets its responsibilities.

In closing, I wish to record my appreciation of the assistance given me in the preparation of this paper by my associates, John K. Dane, Esq., and S. J. MacLellan, Esq.

Bibliography

Biemiller, A. J.: "Radiation and Workmen's Compensation," address at AFL–CIO Conference on Workmen's Compensation, Washington, D.C., April 1958.

Brownlow, James A.: "Workers Must Be Protected Against Radiation Hazards by Adequate Workmen's Compensation," address at AFL–CIO Conference on Workmen's Compensation, Washington, D.C., April 1958.

Cheit, Earl F.: "Workmen's Compensation and Radiation Hazards," Monthly Labor Review, April 1957.

Krebs and Hamilton: "The Role of the States in Atomic Development," 21 Law and Contemporary Problems 182, 196–204 (1956).

McAdams, W. A.: "Radiation—A Safe Industrial Tool," address before President's Conference on Occupational Safety, March 1958.

National Academy of Sciences—National Research Council: "The Biological Effects of Atomic Radiation, Summary Reports," Washington, D.C., 1956.

U.S. Department of Labor: "Occupational Disease Legislation in the United States, 1936," Bulletin 652, prepared by Labor Law Information Service, Sharkey, C. F., chief.

U.S. Department of Labor: "State Workmen's Compensation Laws," Bulletin 161 (revised), August 1957.

EXHIBIT A.—JURISDICTIONS (31) WHOSE WORKMEN'S COMPENSATION LAWS PROVIDE COVERAGE FOR ALL OCCUPATIONAL DISEASES

Alaska	Michigan [2]	Rhode Island
California	Minnesota [2]	South Carolina [1 2]
Connecticut [1]	Missouri [1]	(Tennessee [3])
Delaware	Nebraska [1]	Utah [2]
Florida [1]	Nevada [2]	Virginia [4]
Hawaii	New Jersey [1]	Washington
Illinois [2]	New York [2]	West Virginia [1 2]
Indiana [1 2]	North Dakota	Wisconsin [1]
Kentucky [1 2]	Ohio [2]	United States [5]
Maryland [2]	Oregon [1 2]	
Massachusetts	Pennsylvania [1 2]	

[1] Jurisdictions (11) in which acceptance of workmen's compensation coverage is elective for subject private employers: Connecticut, Florida, Nebraska, New Jersey, Oregon, Pennsylvania, South Carolina, West Virginia. Election, including both traumatic injury and occupational disease coverage, is presumed in the absence of statutory rejection. Kentucky: Affirmative election, including both traumatic injury and occupational disease coverage, is required. Indiana and Missouri: Affirmative election separate from that for traumatic injury coverage is required for coverage of occupational diseases.

[2] Jurisdictions (15) with special provisions for silicosis or asbestosis or other dust diseases.

[3] Tennessee: Workmen's compensation coverage is elective but employer's election, including both traumatic injury and occupational disease, is presumed in absence of statutory rejection. Scheduled disease coverage included in such election may be rejected if broad occupational disease coverage elected in lieu thereof.

[4] Virginia: Workmen's compensation coverage of both traumatic injury and occupational disease is compulsory (acceptance of law conclusively presumed) when private employer has 7 or more employees, but full occupational disease coverage may be rejected if in lieu thereof scheduled disease coverage elected.

[5] Federal Employees' Compensation Act, Longshoremen's and Harbor Workers' Act, and District of Columbia.

EXHIBIT B.—*Jurisdictions (19) whose workmen's compensation laws provide coverage only for listed occupational diseases*

Jurisdictions	Occupational diseases [1]	Radiation injuries specified in schedule
Alabama [3]	Occupational pneumonoconiosis.	None.
Arizona [2 3]	36 listed	Ulceration of the skin or destruction of tissue due to the prolonged exposure to roentgenrays or radium emanations.
Arkansas [3]	38 listed [4]	Diseased condition caused by exposure to X-rays or radioactive substances.
Colorado [2 3]	25 listed	Poisoning or disease caused by exposure to radioactive materials, substances, or machines, or fissionable materials.
Georgia [2 3]	do	Diseased condition caused by exposure to X-rays or radioactive substances.
Idaho [3]	11 listed	Radium poisoning by or disability due to radioactive properties of substances or to roentgenray (X-ray).
Iowa [3]	16 listed	None.
Kansas [2 3]	32 listed	Diseased condition caused by exposure to X-rays or radioactive substances.
Louisiana [3]	22 listed	Do.
Maine [2 3]	16 listed	None.
New Hampshire	5 listed	None.
New Mexico [2 3]	32 listed	All diseases directly traceable to fissionable materials or radioactive materials including ulceration of the skin or destruction of tissue due to prolonged exposure to roentgen rays or radium emanations.
North Carolina [2 3]	27 listed	Radium poisoning or injury by X-rays.
Oklahoma [3]	42 listed	Diseased condition caused by exposure to X-rays or radioactive substances; known diseases directly traceable to fissionable materials or radioactive materials.
Puerto Rico	20 listed [4]	Poisoning from industrial use of radium or other radioactive substances in luminous paints.
South Dakota [2 3]	25 listed	Ulceration of the skin or destruction of tissue due to the prolonged exposure to roentgen rays or radium emanations.
Tennessee [2 3]	9 listed	None.
Texas [2 3]	46 listed	Diseased condition caused by exposure to X-rays or radioactive substances.
Vermont [2 3]	19 listed	Do.
(Virginia) [6]	16 listed	Radium disability or disability due to exposure to radioactive substances and X-ray.

[1] Numbers indicate itemization or subdivisions of diseases or groups of diseases as found in the various laws. Enumeration or grouping of diseases and classes of diseases is not uniform among the States.

[2] Jurisdictions (14) in which acceptance of workmen's compensation coverage is elective for subject private employers: Georgia, Iowa, Kansas, Louisiana, New Mexico, North Carolina, South Dakota, Tennessee, Vermont—employer's single election, including both traumatic injuries and occupational diseases, is presumed in absence of statutory rejection. Alabama, Arizona, Colorado—provision is made for separate election of compensation coverage for occupational diseases, apart from coverage for traumatic injuries, but separate election presumed in absence of statutory rejection. Maine and Texas—affirmative election required which includes coverage for both traumatic injuries and occupational diseases.

[3] Jurisdictions (14) with special provisions for silicosis or asbestosis or other dust diseases.

[4] Arkansas: Commission is empowered to extend schedule after public hearing.

[4] Puerto Rico: Manager of State fund is empowered to extend schedule with approval of Secretary of Labor.

[5] Tennessee: Workmen's compensation coverage is elective but employer's election, including both traumatic injury and occupational disease, is presumed in absence of statutory rejection. Scheduled disease coverage included in such election may be rejected if broad occupational disease coverage elected in lieu thereof.

[6] Virginia: Workmen's compensation coverage of both traumatic injury and disease is compulsory (acceptance of law conclusively presumed) when private employer has 7 or more employees, but full occupational disease coverage may be rejected if in lieu thereof scheduled disease coverage elected.

NOTE.—Comment on specification of radiation injuries: To provide clearly for coverage of *all* radiation injuries the definition or specification of radiation diseases within a schedule should be at least as accurate and as comprehensive as that of New York, viz:

"Radium poisoning or disability due to radioactive properties of substances or to roentgen rays (X-rays) *or exposure to ionizing radiation*" (sec. 3 (2) par. 20). [Italic indicates important addition by 1957 amendment.

Note also the broad definition in Colorado schedule.

EXHIBIT C.—JURISDICTIONS (3) WHOSE WORKMEN'S COMPENSATION LAWS PROVIDE NO COVERAGE FOR OCCUPATIONAL DISEASES

Mississippi: No provisions for occupational diseases.

Montana: Occupational diseases are excluded, except as injuries resulting from fortuitous event, as distinguished from contraction of disease. (Separate public welfare enactment provides benefits for silicosis.)

Wyoming: Occupational diseases are excluded, except such as directly result from injury.

EXHIBIT D.—*Jurisdictions (20) whose workmen's compensation laws have no special limitations on time within which disablement or manifestation must occur for occupational disease to be compensable*

Jurisdiction	Limitations on filing of claim and on occurrence of death in occupational disease cases	Time when limitation period begins to run
Alaska	2 years after injury or death	No case found construing "date of injury" in occupational disease cases.
California	1 year from date of injury or last payment of disability or medical benefits. Death—within 1 year from date of death or date of last compensation benefit but not more than 240 weeks from date of injury or 1 year after death.	"Date of injury" is that date upon which the employee first suffered disability and either knew, or in the exercise of reasonable diligence should have known, that said disability was caused by present or prior employment (sec. 5412). Disability occurs when diseased condition culminates in incapacity to work (*Globe Indem. Co.* v. *Ind. Comm.* (1954) 125 Cal. App. 2d 763, 271 P. 2d 149).
Florida	2 years after injury or death or last payment of compensation. Death must result within 350 weeks after last exposure and must follow continuous disability from disease.	"Disablement" means event of becoming incapacitated from performing work (sec. 440.151(3)) and is to be treated as happening of injury by accident (sec. 440.151(1)(a)).
Hawaii	1 year after injury or death, but in no event later than 5 years after accident or occurrence of injury.	Limitation period runs only from time of accrual of disability (*In re Palama* (1937) 34 Haw. 65).
Kentucky [1]	1 year after last injurious exposure, first distinct manifestation of disease or suspension of compensation payments, whichever occurs last. 1 year after death. Death must occur within 1 year of last injurious exposure or first distinct manifestation, or within 10 years from date of disability if disability continuous.	Limitation periods run from date of last injurious exposure, date of suspension of compensation payments, date diagnosis of such disease is first communicated, or first experience of distinct manifestation "in the form of symptoms reasonably sufficient to apprise (employee) that he has contracted disease" (sec. 342.316 (2) and (3)).
Louisiana	4 months after date of contraction or first manifestation. 6 months after death. If employee in employment less than 1 year, disease presumed nonoccupational. Death must result within 2 years of disablement.	Limitation period does not begin until employee aware that disease is related to employment (*Frisby* v. *International Paper Co.* (1954) (La. app.) 76 So. 2d 621).
Massachusetts	6 months after occurrence of injury or death. Delay may be excused for reasonable cause or lack of prejudice to insurer.	Time of injury is the time when disease is manifest and incapacitates employee for work (cf. *Bergeron's* case (1923) 243 Mass. 366, 137 N.E. 739; *Wheaton's* case (1942) 310 Mass. 504, 38 N.E. 2d 617).
Michigan [1]	6 months after injury or death or cessation of physical or mental incapacity. Within 3 years of injury and within 3 months after disability develops or is apparent, if injury latent or disablement delayed for 6 months and employer has notice or knowledge of injury.	"Disablement" means event of becoming disabled from earning full wages at the work where last subjected to conditions resulting in disability and is to be treated as happening of personal injury (secs. 1, 2, pt. VII). Date of disablement is such date as Board may determine. Limitation period after disablement construed to mean period after knowledge of disability (*Finch* v. *Ford Motor Co.* (1948) 321 Mich. 469, 32 N.W. 2d 712).
Missouri	1 year after injury or death or date of last payment if compensation has been awarded. Death must occur within 300 weeks after accident.	Limitation period for disease runs from time compensable injury becomes reasonably discoverable and apparent (*Ford* v. *American Brake Shoe Co.* (1952), Mo. App. 252 S.W. 2d 649; *Renfro* v. *Pittsburgh Glass Co.* (1939) (Mo. app.), 130 S.W. 2d 165).

See footnote at end of table, p. 200.

EXHIBIT D.—*Jurisdictions (20) whose workmen's compensation laws have no special limitations on time within which disablement or manifestation must occur for occupational disease to be compensable*—Continued

Jurisdiction	Limitations on filing of claim and on occurrence of death in occupational disease cases	Time when limitation period begins to run
New Hampshire	Proceedings for compensation barred unless required notice of injury has been given employer within 1 year of date of accident. Notice is required to be given as soon as practicable after injury; before leaving employment and within 90 days of accident or within 90 days of death, removal of incapacity, or last payment of weekly compensation.	First date of treatment by a licensed physician to be taken as the date of injury for occupational disease (secs. 281: 2, 281: 17).
North Carolina [1]	1 year after death or disability. Death must occur within 2 years after disablement or within 6 years if follows continuous total disability.	"Disability" means incapacity to earn, in same or other employment, the wages received at time of injury and shall be treated as happening of injury by accident. Limitation period for claim for disease begins to run from time of advice by competent physician of existence of disease (sec. 97–58. *Huskins* v. *United Feldspar Corp.* (1954) 241 N.C. 128, 84 S.E. 2d 645).
North Dakota	60 days after date of injury or death; delay excusable for reasonable cause if made within 1 year after injury or death. Death must result within 6 years of injury and within 1 year of cessation of disability; if no disability, within 1 year after date of injury.	"Injury" includes "any disease which can be fairly traceable to the employment" (sec. 65-0102 (8) and (9). No case found on when "disease" occurs; but for injury, limitation period runs from date of accident when injury received, not from date of manifestation (*Bjerseth* v. *N.D. Workmen's Comp. Bureau* (1932) 66 N.Dak. 623, 244 N.W. 515).
Oklahoma [1]	1 year after injury, death, or last payment of compensation. Death must occur within 2 years (5 years if follows continuous disability) of date of accident.	"Injury" means occupational disease as defined. Limitation period for claims runs from date of injury unless tolled by compensation payments; running of period is not postponed to date disability becomes apparent (*Tulsa Hotel* v. *Sparks* (1948) 200 Okl. 636, 198 P. 2d 652 (leading case); *Caquette* v. *American Airlines* (1954) (Okl.) 276 P. 2d 754).
Rhode Island	2 years after disablement or death	"Date of disablement" determined by commission on hearing (sec. 6, art. VIII). Date of contraction expressly declared not to be limiting factor (sec. 4, art. VIII). Limitation period runs from date of accrual of action, viz., when employee incapacitated from earning full wages for at least 3 days (*Rosa* v. *George A. Fuller Co.* (1948) R.I., 60 A. 2d 150).
Tennessee	1 year after beginning of incapacity or death. Death must occur before disability claim is barred.	Limitation period runs from date of discovery or diagnosis of compensable disease (*Wilson* v. *Van Buren County* (1954) Tenn. 268 S.W. 2d 263. Cf. *Griffitts* v. *Humphrey* (1956)__ Tenn.__, 288 S.W. 2d 1).
Virginia	1 year after death or first distinct manifestation or diagnosis of disease. Death must occur within 1 year of first distinct manifestation or diagnosis of disease.	Limitation period runs from time of known diagnosis or of first experience of distinct manifestation of symptoms reasonably sufficient to apprise employee of disease, (sec. 65-49), unless employee mentally incapacitated and without guardian (sec. 65-76). Cf. *Winston* v. *City of Richmond*, 1954, 196 Va. 403. 83 S.E. 2d 728).
Washington	1 year following the date of notice of occupational disease from a physician.	Limitation period (sec. 51.08.140) does not run until employee has notice of disease and of its causal relationship to employment (*Williams* v. *Dept. of Labor and Industries* (1954) 45 Wash. 574, 277 P. (2d) 338. See also *Nygaard* v. *Dept. of Lab. and Ind.* (1958) — Wash. —, 321 P. 2d 257).
West Virginia [1]	1 year after injury or death. Death must result within 6 years from last injurious exposure.	No cases found construing date of injury in disease cases. (For purpose of determining wage basis on which to compute benefits in disease cases "date of injury" is "date of last exposure." Sec. 2539.)

See footnote at end of table, p. 200

EXHIBIT D.—*Jurisdictions (20) whose workmen's compensation laws have no special limitations on time within which disablement or manifestation must occur for occupational disease to be compensable*—Continued

Jurisdiction	Limitations on filing of claim and on occurrence of death in occupational disease cases	Time when limitation period begins to run
United States: Federal Employees' Compensation Act.	60 days after injury; 1 year after death. Delay up to 1 year excusable for reasonable cause in disability claims. Delay up to 5 years after injury or death may be waived if due to circumstances beyond control of claimant.	The term "injury" includes any disease proximately caused by employment (5 U.S.C.A. 790).
Longshoremen's and Harbor Workers' Act and District of Columbia.	1 year after injury or death or last payment.	"Injury" means compensable injury, and in disease cases limitation runs from date of manifestation of disease (*Travelers Ins. Co. v. Cardillo* (1955) C.A.N.Y., 225 F. 2d 137, cert den. 76 S. Ct., 196, 350 U.S. 913).

[1] Jurisdictions with special limitations, not stated herein, for silicosis or asbestosis or other dust diseases.

EXHIBIT E.—*Jurisdictions (30) whose workmen's compensation laws contain special limitations on compensability of occupational diseases*

Jurisdiction	Special time limits within which disablement or manifestation must occur for disease or death from disease to be compensable	Limitation on claims	
		Period within which claim must be made	Time when limitation period begins to run
Alabama	Injury must occur within a period of 5 years of last exposure in each of at least 12 months. Death must occur within 3 years of date of injury. (NOTE.—Act covers only "occupational pneumonoconiosis" as defined.)	1 year after date of last exposure, death, last payment of compensation, or removal of mental incapacity to make claim.	"Date of injury" means date of last exposure "in the employment of the employer in whose employment the employee was last exposed, within a period of 5 years prior to the date of injury, to the hazards of the disease in each of at least 12 months" (sec. 313(10)). Physical incapacity does not toll 1 year limitation (*Geter* v. *U.S. Steel Corp.* (1956) 264 Ala. 94, 84 So. 2d 770).
Arizona [1]	Disability must be total and result within 120 days, and death must occur within 1 year (3 years if follows continuous total disability) from last day of work for employer against whom compensation claimed.	60 days after 1st disablement from disease; 6 months after death.	Limitation period in latent injury cases runs from date the results of the injury become manifest and compensable (*Hughes* v. *Ind. Comm.* (1956) 81 Ariz. 264, 304 P. 2d 1066).
Arkansas [1]	Disablement or death must occur within 1 year after last injurious exposure.	2 years after last injurious exposure; 1 year after death.	Limitation period runs from time when disabling consequences become apparent or discoverable (*T. J. Moss Tie & Timber Co.* v. *Martin* (1952) 220 Ark. 265, 247 S.W. 2d 198).
Colorado [1]	Disability must be total and result within 120 days and death must occur within 1 year (3 years if follows continuous total disability) from last injurious exposure.	60 days after disablement; 6 months after death.	"Disablement" means the event of becoming physically incapacitated from performing any work for remuneration or profit (sec. 81-18-4 (2)).
Connecticut	No claim for disability or death shall be made except while in employment or within 5 years after leaving employment where disease allegedly originated. Death must occur within 6 years of first manifestation of a symptom of the disease, but maximum benefit is payable only if death results within 2 years of first manifestation.	1 year (death, 2 years) after first manifestation of symptom of disease.	"Manifestation of a symptom" means manifestation to employee in such manner as is or ought to be recognized as symptomatic of the compensable occupational disease (sec. 7442).
Delaware	Occupational disease is compensable only when disability has commenced within 5 months after termination of exposure.	1 year after first knowledge that disease is due to employment and within 5 years of last exposure.	Claims barred unless filed within 1 year after employee first acquired knowledge disability "was or could have been or had resulted from employment" (sec. 2361 (c)).
Georgia [1]	Disablement must result within 1 year after last injurious exposure. Death must occur within 1 year (7 years if follows continuous disablement) after last injurious exposure.	1 year after accident or death	"Disablement" means event of becoming actually incapacitated from performing work of last exposure employment or any work for more than ½ of remuneration from such employment (sec. 114-802) and is to be treated as happening of injury by accident. Limitation period begins to run from earliest time disease is identifiable as cause of inability to work (*Free* v. *Associated Indem. Corp.* (1940), 78 Ga. App. 839, 52 S.E. 2d 325).
Idaho [1]	Disablement must be total and disablement or death must result within 1 year (2 years for death following continuous total disability) after last injurious exposure.	1 year after disablement or death	"Disablement" means event of becoming actually and totally incapacitated because of disease from performing work in the last occupation in which injuriously exposed to the hazards of such disease (sec. 72-1205).

See footnote at end of table, p. 204.

EXHIBIT E.—*Jurisdictions (30) whose workmen's compensation laws contain special limitations on compensability of occupational diseases*—Continued

Jurisdiction	Special time limits within which disablement or manifestation must occur for disease or death from disease to be compensable	Limitation on claims	
		Period within which claim must be made	Time when limitation period begins to run
Illinois [1]	Disablement must occur within 1 year (3 years for atomic radiation, beryllosis, silicosis, asbestosis) after last day of last exposure.	1 year after disablement, last payment of compensation, or death if it occurs within 2 years of disablement or last payment.	"Disablement" means event of becoming disabled from earning full wages at work in which engaged at last exposure or equal wages in other suitable employment (sec. 1(e) O.D. Cf. *Carnegie-Illinois Steel Corp.* v. *Ind. Comm.* (1948) 401 Ill. 382, 82 N.E. 2d 444). Non-occupational disability benefit payments under employer-supported group plan toll time limitations, and such payments are credited against compensation payments (sec. 8(j)).
Indiana [1]	Disablement must occur within 2 years after last day of last exposure in covered employment. Death must occur within 2 years of date of disablement or within 400 weeks of disablement and 2 years of fixed period of disability (but cf. sec. 40-2207).	2 years after disablement or death	"Disablement" means event of becoming disabled from earning full wages at work in which engaged at last exposure or equal wages in other suitable employment (sec. 40-2205(d). Cf. *International Detrola Corp.* v. *Hoffman* (1947) 224 Ind. 613, 70 N.E. 2d 844).
Iowa [1]	Disablement or death must occur within 1 year (7 years for death following continuous disability) of last injurious exposure.	2 years of date of injury causing disability or death.	"Disablement" means event or condition of employee's becoming actually incapacitated from performing his work or from earning equal wages in other suitable employment (sec. 85 A. 4). "Date of injury" for limitation period on claim is date of accident, date of "causal injury" (*Otis* v. *Parrott* (1943) 233 Ia. 1039, 8 N.W. 2d 708). "Occurrence of injury" for limitation period on notice is date "when employee found out about disease" (*Jacques* v. *Farmers Lumber & Supply Co.* (1951) 242 Ia. 548, 47 N.W. 2d 236).
Kansas [1]	Disablement or death must result within 1 year (7 years for death following continuous disability) after last injurious exposure.	1 year after disablement or death	"Disablement" means event of becoming actually incapacitated from performing work in last occupation in which injuriously exposed (sec. 44-5a04) and is equivalent to date of accident under W.C. Law, sec. 44-5a06.
Maine [1]	Last exposure must occur in the State. At least 60 days of exposure with employer against whom claim is made. Incapacity must result within 1 year after last injurious exposure. Death must follow continuous disability commencing within 1 year and must occur within 7 years of such last exposure.	1 year after date of accident, death, last payment of compensation. Extended extra year if delay due to mistake of fact. Tolled by physical or mental incapacity. In no case beyond 10 years following accident.	Incapacity to work resulting from disease treated as happening of injury by accident (sec. 58). Date of incapacity from disease equivalent to date of accident (sec. 63. Cf. *Guthrie* v. *Mowry* (1936) 134 Me. 256, 184 A 895; *Hustus's* case (1924) 123 Me. 428, 123 A 514).
Maryland [1]	Disablement or death must result within 1 year (7 years for death following continuous disability) after last injurious exposure.	1 year from date of disablement or death.	Limitation period does not run until employee or someone in his behalf knows or has reason to believe that he has occupational disease and that there is causal connection between disability and occupation (*Mutual Chemical Co.* v. *Pinckney* (1954) (Md.) 106 A 2d 448; *Gracie* v. *Koppers Co.* (1957) 213 Md., 109, 130 A 2d 754)
Minnesota [1]	Disease must have been contracted in employment within 12 months previous to date of disablement.	2 years after employer's report of injury or death to Commission but not later than 6 years after disablement.	"Disablement" means becoming disabled from earning full wages at last employment and is to be treated as happening of accident. Limitation period runs from time it is reasonably apparent disability is compensable (*Nelson* v. *Reid & Wackman* (1949) Minn., 36

			N.W. 2d 544; *Potter* v. *Midland Cooperatives* (1956) Minn., 80 N.W. 2d 59). Date of contraction is date of 1st manifestation of interference with bodily functions (*Cocoran* v. *P. G. Corcoran Co.* (1955) 245 Minn., 258, 71 N.W. 2d 787).
Nebraska	Disability must commence within 2 years subsequent to termination of employment. Death must result within 325 weeks after accident.	6 months after injury or death	"Injury" includes disablement from occupational disease (sec. 48–151 (4)). Time of injury is when disability is experienced. Limitation period does not commence until claimant has knowledge that injury is compensable. (*Keenan* v. *Consumers Public Power Dist.* (1949) 152 Neb. 54, 40 N.W. 2d 261; *Hauff* v. *Kimball* (1956) 163 Neb. 55, 77 N.W. 2d 683).
Nevada [1]	Disability must be total. Unspecified diseases must have been contracted within 12 months of disablement. In case of skin diseases 90 day's residence or 90 days' employment with covered employer required.	4 months after beginning of disability; 6 months after death.	"Disablement" means event of becoming incapacitated from performing any work for remuneration or profit (sec. 27).
New Jersey	Claim forever barred unless made within 5 years after termination of exposure or within 2 years of last payment of compensation to employee if filed by dependents after death.	2 years after last exposure or last payment of compensation or 1 year after employee knew or ought to have known nature of his disability and its relation to employment, whichever is later.	Limitation periods run from date of cessation of exposure in employment, date of last payment of compensation, or after "employee knew or ought to have known the nature of his disability and its relation to his employment" (secs. 34: 15–33, 34: 15–34). Compensation right accrues at time of disablement, not time of exposure. (*Biglioli* v. *Durotest Corp.* (1957) 44 N.J. Super. 93, 129 A 2d 727).
New Mexico [1]	Disability must result in 120 days, or death occur within 1 year (3 years if follows continuous compensable disability) from last day of work for employer against whom compensation claimed.	60 days after disablement; 6 months after death.	Limitation period in latent injury case does not run while injury is not or could not be discovered (*Letteau* v. *Reynolds Elec. and Eng. Co.* (1955) 60 N.M. 234, 290 P 2d 1072).
New York [1]	Disease (except specified latent diseases) must have been contracted within 12 months previous to date of disablement, unless contraction and disablement occur during same continuous employment. For death from specified latent diseases where previous claim or determination of compensability has not been made disease must have been contracted within 5 years previous to death.	years after accident or death; or in specified latent disease cases 90 days after disablement or after knowledge that the disease is or was due to the nature of the employment, whichever is later.	Disablement to be treated as happening of accident and means act of becoming disabled from earning full wages at work of last employment (secs. 37, 38). "Date of disablement" is such date as the workmen's compensation board may determine on the hearing on the claim (sec. 42).
Ohio [1]	Disease must have been contracted in employment within 12 months previous to disablement. Death must result within 2 years of injury or follow continuous disability or compensation.	6 months after disability began or death occurred, except for death benefit claims of wholly dependent persons.	Limitation period runs from date disability begins (sec. 4123.85). "Disability" means impairment of earning capacity (*State ex rel. Waller* v. *Industrial Commission* (1943). Ohio App. 60 N.E. 2d 680. Cf. also *State ex rel. Raymond* v. *Ind. Comm.* (1942) 14 Ohio St. 233, 42 N.E. 2d 992).
Oregon [1]	Claims void unless filed within 3 years after last exposure.	3 months from date of becoming disabled or of being informed by physician of occupational disease.	No pertinent compensation cases found; but see, *Ptukkula* v. *Pillsbury Astoria Flouring Mill Co.* ((1935) 150 Or. 304, 42 P 2d 921), stating that general statutory limitation not tolled because employee does not realize nature or seriousness of occupational disease.
Pennsylvania [1]	Disability or death must occur within 4 years after date of last employment in occupation or industry to which disease is peculiar.	16 months after beginning of disability, death or most recent compensation payment, if any.	Limitation period runs from date when compensable disability begins and depends on knowledge based on competent medical diagnosis (*Ciabattoni* v. *Birdsboro Steel Foundry & Machine Co.* (1956) 386 Pa. 179, 125 A 2d 305).

See footnote at end of table, p. 204.

EXHIBIT E.—*Jurisdictions (30) whose workmen's compensation laws contain special limitations on compensability of occupational diseases*—Continued

Jurisdiction	Special time limits within which disablement or manifestation must occur for disease or death from disease to be compensable	Limitation on claims	
		Period within which claim must be made	Time when limitation period begins to run
Puerto Rico	Disease must have been contracted within 12 months prior to date of disability. Death must result within 2 years of "accident."	No provision	Workman must present himself to physician within 5 days of "accident"; delay excusable. No cases found construing "accident" with respect to disease.
South Carolina [1]	Disease must have been contracted within 1 year after last injurious exposure. Death must result within 2 years (6 years if follows continuous total disability) after accident.	1 year after accident or death	"Disablement" means event of becoming actually incapacitated from performing work in last exposure employment and is to be treated as injury by accident (sec. 72-252, 253).
South Dakota [1]	Disablement or death must result within 1 year (5 years for death following continuous disability) after last injurious exposure.	1 year after disablement, death, or last payment of compensation.	"Disablement" means event of becoming actually and totally incapacitated from performing work in last occupation where injuriously exposed (sec. 64.0804(b)).
Texas [1]	Incapacity or death must result within 1 year (360 weeks for death following continuous compensable incapacity) after last injurious exposure.	6 months after 1st distinct manifestation of disease, death, or removal of incapacity.	Industrial Accident Board may waive strict compliance for "good cause" (art. 8307, sec. 4a), e.g. reasonable failure to realize condition or recognize connection with employment. (See *Highway Insurance Underwriters* v. *Smyrl* (1954) — Tex. —, 267 S.W. (2d) 265; *Texas Employers Ins. Ass'n.* v. *Hughey* (1954) — Tex. —, 266 S.W. (2d) 456).
Utah [1]	Partial permament disability must occur within 2 years of last exposure and within 2 years of filing of claim. Total disability must result within 120 days, or death within 1 year (3 years if follows continuous disability) from last day of work for employer against whom compensation claimed.	60 days after cause of action arises; within 6 months after death.	Cause of action arises when disease reasonably discoverable as compensable (*State Insurance Fund* v. *Ind. Comm.* (1949) Utah, 209 P. (2d) 558)).
Vermont [1]	Disablement must be total and result within 2 years after last injurious exposure; death must occur during employment or follow continuous disability within 7 years after the last exposure.	1 year after injury or death or last payment of compensation.	"Date of injury" is date of disablement and shall be equivalent to date of accident (sec. 8). "Disablement" means total inability to perform any work in his then or any other occupation (sec. 3).
Wisconsin [1]	Right of employee to apply to commission for settlement of controversial claims shall not extend beyond 6 years from "date of injury" (i.e. last day of work for last employer whose employment caused disability), date of death or last payment of compensation.	2 years after "date of injury" or death, or after employee or dependent knew or should have known nature of disability and its relation to employment.	"Date of injury" in case of disease is last day of work for last employer whose employment caused disability (sec. 102.01(2)). During employment date of injury is date of 1st wage loss (*Wagner* v. *Ind. Comm.* (1956) 273 Wis. 553, 79 N.W. 2d 264). Limitation period does not run until employee knows or ought to know the nature of disability and its relation to employment, disability being only such physical incapacity as results in wage loss (*Reinhold* v. *Ind. Comm.* (1948) 253 Wis. 606, 34 N.W. 2d 814; *Delta Oil Co.* v. *Ind. Comm.* (1956) 273 Wis. 285, 77 N.W. 2d 749).

[1] Jurisdictions with special limitations, not stated herein, for silicosis or asbestosis or other dust diseases.

EXHIBIT F.—*Jurisdictions (17) whose workmen's compensation laws provide only limited medical benefits for occupational diseases*

Jurisdiction	Limitations		Additional benefit which administrative agency is authorized to provide
	Period	Amount	
Alabama [1]	6 months	$1,200.00	
Alaska	4 years		
Arizona [2]		1,000.00	
Colorado [3]		1,500.00	
Georgia	10 weeks	1,125.00	Such additional time and amount (up to $375) as will tend to lessen disability period.
Iowa [4]		1,500.00	$1,000.
Kansas [5]	120 days	2,500.00	Longer period in extreme cases.
Kentucky		2,500.00	
Louisiana		2,500.00	
Pennsylvania [6]	6 months	450.00	Such further care as will result in restoring earning power to a substantial degree.
South Carolina	10 weeks		Such additional time as will tend to lessen period of disability.
South Dakota [7]	20 weeks	1,000.00	
Tennessee	1 year	1,500.00	
Utah [8]		1,283.33	$641.68 in special cases of prolonged hospitalization.
Vermont [9]		2,500.00	
Virginia	60 days		10 months (i. e., up to 1 year total period).
West Virginia [10]		1,600.00	$800 for vocational rehabilitation in exceptional cases of permanent disability.

[1] Covers only "occupational pneumonoconiosis" as defined.
[2] Medical benefits up to $1,000 are provided for total disability from any disease in schedule; medical benefits up to $500 are provided for partial disability from certain of the diseases in schedule. Full medical coverage is provided for traumatic injuries.
[3] No compensation payable for partial disability from disease; limitation period of 6 months additionally applies in traumatic injury cases.
[4] $500 for medical and surgical services; $1,000 for hospital services and supplies.
[5] Special medical limitation applies to silicosis.
[6] $450 for medical and surgical services, medicines and supplies plus hospital treatment, services, and supplies and orthopedic appliances and prostheses for 6 months.
[7] $300 for medical and surgical services; $700 for hospital service.
[8] Provided only for total disablement from disease. Full medical provided for traumatic injuries.
[9] Provided only for total disablement from disease. Special medical limitation for silicosis.
[10] There are 12 jurisdictions whose workmen's compensation laws have special medical limitations for silicosis or asbestosis or other dust disease cases: Alabama, Arkansas, Colorado, Illinois, Kansas, Maine, Nevada, North Carolina, Ohio, Texas, Vermont, West Virginia.

NOTE.—There are 33 jurisdictions whose workmen's compensation laws provide full medical coverage for compensable traumatic injuries and occupational diseases (some diseases excepted; see e.g., note 10 above) either by specifying full coverage (California, Connecticut, Delaware, Hawaii, Idaho, Illinois, Massachusetts, Minnesota, Nebraska, New York, North Dakota, Puerto Rico, Texas, Washington, Wisconsin, United States.—Federal Employees' Compensation Act, Dangerous Cargo and Longshoremen's and Harbor Workers' Compensation Acts) or by authorizing administrative agency to provide benefits or additional benefits without restriction (Arkansas, Florida, Indiana, Maine, Maryland, Michigan, Missouri, Nevada, New Hampshire, New Jersey, New Mexico, North Carolina, Ohio, Oklahoma, Oregon, Rhode Island). Note that in Idaho and Nevada only total disability from disease is compensable.

Of the jurisdictions without occupational disease coverage in their workmen's compensation laws, Mississippi specifies full medical coverage, Wyoming authorizes the court to allow necessary hospitalization benefits (in addition to stated amounts of initial benefits) for additional 6-month periods, Montana provides for basic medical benefits for 36 months or up to $2,500, with additional benefits authorized for hospitalization in total disability cases.

EXHIBIT G. STATE RADIATION PROTECTION REGULATIONS

1. States with strong radiation codes: California, Massachusetts, Michigan, New York, Pennsylvania, Texas.

2. States with some radiation protection statutes or regulations which do not meet the standards recommended by the National Committee on Radiation Protection:

(*a*) The following States have a radiation protection code under consideration: Arizona, Kansas, Maine, Minnesota, South Carolina, Virginia.

(*b*) The following States require registration of all radiation sources: Illinois, North Dakota, South Dakota, Utah, Wyoming.

NOTE.—Section 5 of the model act for radiation protection, suggested by the National Committee on Radiation Protection, requires the registration with a State agency of every radiation source.

(*c*) States whose statutes or regulations do not require the registration of all radiation sources: Arkansas, Colorado, Connecticut, Delaware, Florida, Georgia, Indiana, Kentucky, Mississippi, New Hampshire, New Jersey, New Mexico, Ohio, Oregon, Rhode Island, Tennessee, West Virginia, Wisconsin.

[1] Jurisdictions with special limitations, not stated herein, for silicosis or asbestosis or other dust diseases.

3. States with no effective regulation of radiation sources: Alabama, Idaho, Iowa, Louisiana, Maryland, Missouri, Montana, Nebraska, Nevada, North Carolina, Oklahoma, Vermont, Washington.

PART IV

ADDRESS AT AFL–CIO CONFERENCE ON WORKMEN'S COMPENSATION, APRIL 15, 1959, ON RADIATION AND WORKMEN'S COMPENSATION, BY A. J. BIEMILLER, DIRECTOR, LEGISLATIVE DEPARTMENT, AFL-CIO

This conference is pinpointing the deficiencies in workmen's compensation legislation and high on the list of shortcomings is the failure of the compensation systems to adapt to new hazards and new needs. Foremost among the new industrial hazards posing new problems is atomic radiation.

Most of us are only distantly aware of this strange new hazard because we haven't come into direct contact with it. Time after time I have run into the question: Why are you labor people concerned about this radiation business? And in discussing this question, I have encountered many comments reflecting a widespread lack of understanding of the scope and nature of radiation hazards.

I would like this afternoon to discuss some of these common misimpressions and to set on the table some of the basic facts which explain why we should be deeply concerned with compensation inadequacy in this field.

The first misimpression is that atomic activity is nearly all military activity and that, except for a few nuclear power reactors and some medical uses, there simply is not much radiation to be concerned about in industry today. This statement could have held true a decade ago. But today radiation is no longer a limited, isolated hazard confined to some hidden atomic installations. It is now—not tomorrow, but now—already a commonplace industrial tool with its use spreading rapidly and widely.

Not all uses are equally hazardous, of course, and in most uses only a handful of men are normally subject to exposure, but nevertheless the possibility of exposure to harmful radiation now exists in literally thousands upon thousands of industrial operations, and in other thousands of nonindustrial operations which also employ many workers.

When speaking of atomic energy most of us immediately think of nuclear powerplants, the most dramatic and most publicized area of growth. Such powerplants and supplier operations providing the nuclear materials, present the most serious radiation safety questions and involve the largest concentrations of workers. But radiation uses range far into other fields.

Industry is using radiation in everyday operations for measurement, for inspection, and for product control purposes, and for changing the characteristics of various materials. There are also the huge number of medical, agricultural, and research applications, and the expanding activity in transportation of radioactive materials.

The statistics are limited, but we can consider several of them: (1) On nuclear reactors, there are only two atomic powerplants now functioning, but the number of research and experimental reactors has been

mushrooming. At the end of last year there were already over 150 different civilian reactors in operation or construction in this country.

(2) More striking is the growth in industrial use of isotopes of sufficient radioactivity to require a license from the Atomic Energy Commission.

Of the 500 largest industrial corporations in the United States today, 250—fully half—already use radioisotopes for various purposes.

(3) All told, more than 1,200 industrial firms are now licensed to use radioisotopes. Many use several isotopes and in different locations, so that the number of applications run way up in the thousands.

There are also over 2,000 licensed nonindustrial users, including universities, hospitals, laboratories and others whose employees are also subject to workmen's compensation.

(4) In the first 11 months of 1957 alone, licenses were issued to 612 new industrial users and over 900 other users.

(5) In addition, most users now use considerably larger quantities of radioactive material than earlier. Total shipments of radioisotopes by the AEC last year almost equaled—it was well over 70 percent of—the grand total shipped in all the 10 preceding years put together.

(6) One more statistic. The users are not in one or a few areas but all over the country. As a matter of fact, there are licensed users in every State. In 42 States, the District of Columbia and Hawaii, there are more than 10 users each. In 31 States there are over 25 users each and in 9 States there are already over 100 users of radioactive isotopes.

I cite these numbers to demonstrate that radiation is already a current and not merely a future occupational hazard.

But the mere fact that radiation exposure for workers is now so widespread a possibility does not in itself satisfy many people that special legislative treatment is necessary. There is an awareness that radiation is an unusual, a peculiar hazard. There is a good deal of fear about it, but the full extent of some of its peculiarities is not adequately appreciated.

Let me list some of the features of radiation which explain why it is in a distinct hazard class by itself, why it requires special safety measures and special workmen's compensation treatment. Some other hazards share one or several of its features, but none approach radiation's unique combination of major peculiarities.

First, a man can be exposed to a harmful dose of radiation and not be at all aware of it. Radiation cannot be seen, it cannot be heard and it cannot be felt. Because the hazard cannot be detected by man's senses, the risk often cannot be avoided merely by reasonable care as in the case of most occupational hazards.

Second, there are actually many different forms of radiation hazard. There are different types of radiation, each with different penetrating power and different effects. Materials contaminated by radiation present further problems. External radiation involves difficulties quite different than the threat of internal absorption of radioactive particles.

Third, it is not clear how much is harmful. Scientists have recommended certain exposure limits, but they generally acknowledge that there is no clear-cut dividing line between safety and ill effects and that the only truly safe rule is the less radiation the better.

There are other complications or exposure limits. Some people are apparently more radiosensitive than others. Also, different parts of the body have different sensitivity. A large dose for the less sensitive parts may carry little danger in comparison to a smaller dose to the entire body or particularly sensitive organs.

Fourth, and now we get to some of the most perplexing aspects, radiation has a cumulative effect. The amount absorbed at any one time may not in itself be dangerous, but may prove seriously damaging in combination with earlier exposure, even though separate exposures may be years apart.

It is the total amount accumulated over the years that counts. There is apparently little recovery and there are no fresh starts. Whenever a worker absorbs any radiation, he reduces permanently the dosage to which he may be safely exposed in the future.

Finally, the harmful effects take many forms. Scientists do not yet know the full story of effects of radiation on human beings. A huge dose at one time does have certain quickly evident injurious effects, but smaller or long-continued exposure may have varied effects, and this is where many difficulties arise.

For one thing, and this is extremely important, injury may not be immediately apparent. The reaction may be long delayed, with damage not developing noticeably until years after the decisive exposure. In some instances radiation effects have remained latent for as long as 25 or 30 years before emerging.

Even more troublesome, the ill effects of radiation may never become apparent or measurable even though they are quite real. Overexposure may produce, not an identifiable radiation disease, but rather increased susceptibility to various fairly common diseases, most notably leukemia and other cancers. In any one individual it may not be possible with the medical knowledge now at hand to determine if leukemia, for example, was radiation induced or due to other causes.

Radiation also contributes to a shortening of the lifespan. Extensive tests on animals reveal an aging effect on living tissue and weakened resistance to disease which brings on death earlier than usual. In other words, the average worker who absorbs a good deal of radiation may have no evident ill effects and ultimately will die from the same ailments as other persons—only sooner.

Beyond this, there is also a threat of genetic damage, an affect not on the worker alone but on his offspring. Radiation affecting the reproductive cells might mean sterility or, if an affected worker can have children, his descendants might be adversely effected.

A news story in this weekends papers, while not bearing directly on occupational hazards, dramatically illustrated the devious effects of radiation and the type of new knowledge being uncovered daily on what radiation does to human beings. The story reported results of a study of children of mothers exposed to radiation from X-ray diagnoses during pregnancy. These children had twice as much leukemia and a higher rate of other malignancies than children of mothers who had no radiation doses during pregnancy.

Thus far we have, as far as we know, been rather fortunate in our industrial radiation injury experience. We have had what appears to be a good safety record, not because radiation is safe to work with, but because exceptional safety steps have been taken; because under close Government direction knowledgeable specialists have been used,

necessary safety precautions have been observed and radiation control devices have been given top priority. Safety, not economy or financial factors, has been the guiding consideration thus far.

But the fact of a laudable record to date breeds an unwarranted sense of security. As civilian uses of atomic energy expand, potentially dangerous radioactive materials may be supervised by persons less familiar with the hazards, persons neither as alert to the hazards or as competent to control them, persons more concerned with economy than with maximum protection for workers.

So we run the risk of an increasing number of radiation injuries. This is why we insist on scrupulous enforcement of all necessary radiation safety standards. This is why we oppose any relaxation in the present Federal system of atomic safety controls and why we oppose any relinquishing of the existing Federal responsibility in this field to the States. And it is why we seek the development of workmen's compensation legislation adequate to meet the special needs presented by radiation cases.

Our concern does not rest simply on anticipation of a rush of radiation injuries, however. Our concern is probably greater than the potential number of injuries alone might warrant.

We fear simply that (*a*) if a number of radiation incidents were to occur, or (*b*) if it were suddenly discovered that the continued low-level exposure received by many workers, which we have assumed is safe, is actually injurious, or (*c*) if there were suddenly a major dramatic nuclear accident, we may have panic touched off and we may suffer a drastic loss of confidence of workers and the public in the wisdom and safety of atomic uses.

The serious danger of loss of worker confidence is compounded if the worker is aware that compensation protection is nonexistant or inadequate in the event he should be hurt by radiation.

Let me repeat: We need effective safety standards and adequate compensation legislation against radiation hazards to reassure workers in this field, to offset the potential damage of the occasional incident, to avoid a breakdown of worker confidence which could seriously disrupt and set back all peaceful atomic development.

I trust we do not have to wait for catastrophe and tragedy as a motivating force for enactment of decent compensation protection. It is now more than 30 years since the first eruption of the famed radium poisoning of the young women who painted luminous dials on watches. Various States took account of this one limited type of radiation hazard only after its reality was so tragically demonstrated.

Now a similar threat of major tragedy is ripe again. But this time we have ample forewarning and a substantial backlog of experience. Let us move to gain needed compensation legislation without waiting for tragedy to provide the spark for action.

Unfortunately, except for some mild interest at gatherings of State workmen's compensation officials and except for some limited steps taken by several States, there is an abysmal record of failure on the part of the States to adjust their compensation laws to meet the peculiar problems and needs raised by radiation.

I will not attempt here to provide a State-by-State rundown or any overall tabulation. Many of you have seen the general summary which Prof Earl Cheit presented at the AFL–CIO Conference on Radiation Hazards in February 1957.

Suffice to say that almost all the States fall short on at least one or two of even such elementary points as (a) assurance that radiation disease is covered, (b) a statute of limitations that allows for the long-delayed nature of some radiation effects, and (c) provision for full medical care for a worker suffering radiation ill effects.

Practically no consideration has been given to the more complex problems such as those arising out of the difficulties of measuring radiation effects or of linking a specific injury to a specific exposure.

In short, the States do not provide adequate coverage and are moving slowly, or typically not at all, to meet the need. This is true despite a great burst of interest in many States in atomic activities. The interest is directed toward promoting or attracting atomic industry, however, and not to providing compensation protection.

If thus far not a single State has developed fully desirable legislation, how long would it be necessary to wait for all or any appreciable number to do so?

This situation cried for separate special treatment at the Federal level as the only means of gaining necessary protection across the country in the reasonably near future. Actually, Federal action is peculiarly appropriate in this particular field, as already reflected in other Federal actions.

Thus, there is a Federal safety program to meet the peculiar and specially hazardous nature of radiation. Observance of Federal standards and a Federal license is required of all who wish to use certain radioactive materials or who wish to construct or operate a nuclear reactor.

The Federal Government has also, in September 1957, enacted Federal public liability insurance for the nuclear reactor industry. This Federal indemnity program offers financial protection to industry against public claims arising out of an atomic accident.

But there has been no corresponding Federal action to provide for the needs of injured workmen. In light of the continued reluctance and refusal of the States to furnish the needed protection, the Congress should not hold off any longer.

The Joint Congressional Committee on Atomic Energy has planned hearings during the middle of June on this vital subject. We hope at that time to do our best to persuade the Congress that it must now move ahead to provide assurance of adequate compensation protection for all workers subject to radiation exposure.

PART V

WORKMEN'S COMPENSATION

EXCERPT FROM SECTION V OF THE REPORT OF THE SPECIAL COMMITTEE ON ATOMIC ENERGY LAW, PREPARED FOR THE ANNUAL MEETING OF THE AMERICAN BAR ASSOCIATION, 1957

One of the most immediate problems confronting the lawyer in the atomic energy field arises in connection with workmen's compensation laws. There can be no reasonable doubt but that these laws will

require a reexamination in the light of the peculiarities of radiation overexposure. It would seem to be altogether proper for the American Bar Association Special Committee on Atomic Energy Law to initiate such reconsideration, either by recommending to the National Conference of Commissioners on Uniform State Laws that it take appropriate action or, in the event the national conference does not desire to do so, by undertaking the preparation of a proper study of the subject through some other means. The following is a catalog of some of the special problems that arise in this field.

A. Definition of compensable injuries

1. Meaning of "arising out of and in the course of employment." Under typical interpretations these words limit recovery to accidents that occur during working hours and in usual places where work is carried on. Also, in some jurisdictions the manifestation of the injury must occur on the premises.

Moreover, since manifestations of injury from overexposure to radiation almost always are delayed the phrase "in the course of employment" involves problems. For example, would a worker who is allowed to obtain possession of radioactive material through employer's negligence or during normal operations and then accidentally keeps it on his person overnight or for a week or month have been injured "in the course of employment"?

2. Meaning of "occupational disease," especially in connection with chronic exposure. Some States provide no statutory coverage for occupational diseases. Others provide for specific radiation injuries so phrased as apparently to exclude those not listed. Still others may be interpreted as covering accidental overexposure of the acute type but not long continued less intense chronic overexposure.

Manifestations of radiation injury are always delayed, and proof that a particular radiation exposure is the cause of a certain injury is often impossible because of natural background radiation and the cumulative effect of radiation overexposure, or because radiation injuries such as cancer, cataract, or sterility can also result from other causes. Yet statistics show chronic exposure is very likely to cause or to be a contributing factor in causing these injuries. Therefore, the question arises as to what action should be taken to cover adequately overexposure to radiation as a compensable injury?

Assuming statutory coverage, the next question is what should be done to draw the line by legislative enactment or by administrative rulings between diseases unmistakably caused by occupational overexposure to radiation and the same diseases caused by nonoccupational overexposure or even nonradiation sources? Actual proof is difficult and some appropriate substitute in the form of statutory presumptions may become necessary.

3. How should cumulative effects be handled? The delayed manifestations of radiation injuries and the cumulative effect of overexposure present difficulties when, for example, a worker shifts from one employer to another.

Cumulative chronic exposure in different employments may cause manifestations in the last employment much out of proportion to the radiation overexposure there received. Or, manifestations from earlier overexposure may not show up until the worker is in a subsequent employment and the radiation causing the particular injury

becomes impossible to identify. Or, without apparent manifestation of injury even though the employee has been subjected to chronic exposure in several employments, it may become necessary because of total radiation received to cease all future exposure.

What changes in present statutory or administrative provisions should be made to take account of these and other similar matters? Should apportionment among employers be provided for? So-called second injury funds become of especial significance.

4. How should radiation injuries causing no wage loss or diminution of earning power be handled? Workmen's Compensation and occupational disease statutes normally contain provisions limiting compensation to injuries that result in total or partial job disability. The test usually applied is (1) disability to use various parts of the body, such as hands, eyes, etc. in the same manner as before the accident, or (2) loss of earning power in terms of physical ability to do the work possible before injury. States vary in the strictness of their wage loss test. Again it must be remembered that radiation overexposure is cumulative and manifestations may be long delayed, therefore at least delaying earning power loss.

Again, a question arises as to whether or not certain serious injuries such as sterility, or shortened life span (the effects of which would appear during the years of retirement), or genetic damage, none of which cause wage loss, should be compensable as occupational injuries. Still again, what should be done to compensate for receiving total permissible dose of radiation and then later needing extensive medical X-ray treatment or other exposure?

B. Amount and types of awards for compensable injuries

Radiation injuries are cumulative, long-delayed in manifesting themselves, long-lasting in effect, and calling for unique skills in treatment frequently not readily available in most places. Therefore, attention should be given to the following questions:

1. Are radiation injuries sufficiently unique to call for modification of cost limits and time limits on standard medical aid provisions?

2. Should provision be made for availability of radiation specialists for all radiation injury cases? Should premanifestation treatment be required?

3. Are existing scales of benefits for accidental injuries fair as applied to radiation injuries?

4. Are radiation injuries sufficiently unique and the number of specialists sufficiently small to call for special Federal action to handle radiation problems?

5. What should be done for workers, technicians, and professionals who have had all the exposure they can stand for their lifetimes without incurring serious injuries, and who therefore will be unable to make further use of their special skills?

6. Should vocational rehabilitation aimed at training these men in new skills of comparable value and prestige be one of the benefits of compensation awards for radiation injuries?

7. What should be done about personnel who, after they have received their total lifetime allowance of radioactivity, can find equally

well-paid positions having no radiation hazards but who lose very important seniority rights as a result of change in employment?

C. "Notice of injury" and "filing" requirements

Statutes covering "injuries by accident" generally start the period for notice of injury and filing of claims as of the time of the "accident." Under a few statutes notice may be delayed until the injury manifests itself. Certain statutes make exceptions for hidden or latent injuries. Some permit delay until the employee knows of the injury's connection with his occupation. "Occupational disease" clauses sometimes start the periods of limitation running at the time of the latest injurious exposure, while others commence when disability appears. Notice of injury provisions run as short as 60 days and as long as 2 years following cessation of employment. Some statutes contain overall filing of claims limitations of from 1 to 5 years, whereas others set the limitation in terms of an elapsed period after the termination of employment. In some radiation injury situations all statutes will seemingly have too short periods of limitations to allow proper notices of injury and filing of claims by the injured worker.

What should be done to make time limitations fair to the workers? If extended to unduly long periods, how can employers be protected against spurious claims, loss of evidence, effect of additional exposure from other sources which could aggravate or cause injury, etc.? Should routine examinations for possible evidence of radiation injury be required periodically as well as when the worker terminates his employment? Should some central filing scheme be set up?

The foregoing are some of the emerging workmen's compensation questions and there is no question of their importance. Appropriate steps may well be taken to refer this matter to the National Conference of Commissioners on Uniform State Laws with a suggestion that it would seem to be an especially appropriate field within which to prepare a model act to guide State legislators.

It has taken some years for private atomic industry to get underway, and, in fact, the principal impact of the new development is still around the corner. Yet the legal problems are beginning to identify themselves rather clearly. Your committee feels that the coming year should mark an end of the period of watchful waiting and the beginning of definitive action.

Respectfully submitted.

WILLIAM T. GOSSETT,
EVERETT L. HOLLIS,
HANS A. KLAGSBRUNN,
CLYDE O. MARTZ,
PAUL W. MCQUILLEN,
CHARLES R. NORBERG,
CASPER W. OOMS,
OSCAR M. RUEBHAUSEN,
E. BLYTHE STASON,
Chairman.

PART VI

EXTRACTS FROM "SUGGESTED STATE LEGISLATION—PROGRAM FOR 1959"—COUNCIL OF STATE GOVERNMENTS

Atomic Energy and Radiation Proposal

* * * * * * *

(C) RADIATION PROTECTION

There is general agreement among scientific authorities that workers and the general public must be protected against unnecessary radiation which may occur with the increasing use of radioactive sources. There has been less agreement, however, as to the kinds of regulation which should be employed and as to who should enforce them.

The Conference on the States and Atomic Energy Development, in Chicago during May 1957, noted the fact that the activities involved here concern both the Federal and State Governments, since protection of the public health and safety is a major responsibility of the States. That conference concluded that "Sole authority in this area should not be vested in either level of government. * * * Cooperation between the States and the Federal Government in the development and enforcement of health and safety standards pertaining to the use of nuclear materials is essential."

The elements of desirable State radiation protective regulation are becoming much clearer as the fruits of extensive conference, discussion, and increasing experience. These might include the following:

1. Statutory provisions adopted by States to regulate radiation exposure should be simple and minimal, leaving to administrative rules and regulation the establishment and enforcement of standards. Flexibility, which can be achieved in this manner, is essential in light of our constantly expanding knowledge of the subject matter.

2. Regulations adopted in each State should be in substantial conformity with nationally accepted standards, such as those developed by the National Committee on Radiation Protection and by the Atomic Energy Commission.[1]

3. The various fields of radiation hygiene and safety—irradiation of employees and others; pollution of air, water, and ground and the disposal of radioactive wastes; and transportation of radioactive materials—should be comprehended in regulations established, with advance review and coordination by the State coordinator of atomic energy development and study by the other agencies and departments affected.

4. As a means of assuring that the various governmental agencies and levels of government concerned and the public, generally, may be informed as to the location and nature of radioactive sources, it appears desirable for the State to require that such sources should be registered in a manner not difficult of compliance and with appropriate exemptions for radioactive sources not presenting significant hazards.

---

[1] Copies of these standards may be obtained from, respectively, the National Committee on Radiation Protection, Bureau of Standards, Department of Commerce, Washington 25, D.C., and the Division of Licensing and Regulation, U.S. Atomic Energy Commission, Washington 25, D.C.

In only seven States as of mid-1958 have there been adopted comprehensive regulations of the type outlined and recommended above: California, by the department of industrial relations, in January 1955; Connecticut, by the department of health, in October 1957; Massachusetts, by the department of labor and industries, effective December 1957; Michigan, by the department of health, in December 1957; New York, where two codes were adopted in 1955—a Radiation Sanitary Code by the health department, and a Radiation Industrial Code by the department of labor; Pennsylvania, by the department of health, in October 1956; and Texas, by the board of health, effective September 1956. In all of these States but California, the registration of radiation sources is required. Registration is required also in eight other jurisdictions, in several of them as part of a transitional period pending adoption of comprehensive regulations.

* * * * * * *

(E) WORKMEN'S COMPENSATION LAWS AND RADIATION INJURY COVERAGE

When workmen's compensation laws were initiated a half a century ago, their main purpose was to eliminate the uncertainties facing employees in obtaining damages for injuries at common law or under employers' liability laws. Theretofore, the employee who was injured during his employment had to bring an action against his employer for damages and was frequently barred from recovery because of the defenses of "assumption of risk," "contributory negligence," or the "fellow servant" rule. By the new laws, industry was made to bear the burden of the damages so long as the injury occurred during the course of employment and the employee was in some way furthering his employer's business. The cost of work injuries thus has come to be considered part of the expense of production.

In time, "injury" was expanded to mean "disease" and most workmen's compensation acts were amended to define and enact further provisions regarding the various ways in which an employee could be injured during his employment. As new risks of occupational disease came into being, or came to be identified, workmen's compensation acts, in most cases, were amended to include them.

The increased and increasing use of atomic energy for peaceful purposes, in industry and elsewhere, will result in the greater incidence of diseases caused by exposure to ionizing radiation and associated materials. This is a problem facing the States even now, not one just of the future. Contrary to widely entertained notions, even today the overwhelming majority of workers engaged in pursuits which bring them into contact with radiation are employees of private business—and thus subject to State workmen's compensation laws—rather than employees of the Atomic Energy Commission—and thus excluded from State law coverage. As an illustration, the Atomic Energy Committee of the International Association of Industrial Accident Boards and Commissions (IAIABC) in September 1957, reported that as of the middle of that year, 112,000 workers for private contractors with AEC were employed on projects which involved radiation exposure whereas the entire staff of the AEC at that time numbered less than 7,000.

34434—59——15

Some facts concerning the nature of injuries which result from exposure to radiation should be noted. It is a characteristic of radiation that it has a cumulative effect on the body. Many sources contribute to the radiation which the body receives. Cosmic rays from outer space, radioactive elements in soil, air, and water—all contribute to what is called natural background radiation. X-rays and radium produce radiation to which we have been exposing ourselves for many years. The newer sources of ionizing radiation which we have known less than a score of years add to these.

Research based on increasing information available to us indicates that amounts of radiation received gradually and over a long period of time are less harmful than brief exposures to the same total amounts of radiation; but any exposure, no matter how slight, may be harmful. Considerable study has gone into determining tolerable limits of exposure, and safety regulations have been developed on the basis of these studies. It has been urged in this connection—by many scientific authorities, the International Association of Industrial Accident Boards and Commissions, and others—that cumulative exposure records be maintained for all persons regularly in contact with radiation hazards.

Overexposure to radiation can result in leukemia, eye cataracts, tumors, skin burns, cancer, and can produce genetic effects. Some effects of overradiation resemble the speeding up of the ordinary aging process of the body. It is noteworthy that many of these conditions can result from factors or causes other than overexposure to radiation.

The responsibility of the States, in cooperation with Federal agencies, for instituting radiation regulations to protect workers and others has been dealt with elsewhere in this report. (See statement on "Radiation Protection.") Over and above that, the States, since they have asserted and assumed responsibility for providing compensation for occupational hazards, now face a real challenge to adjust their systems to provide workers with equitable coverage for radiation-induced diseases. As noted by the U.S. Department of Labor in an August 1957 survey of "State Workmen's Compensation Laws" (Bull. 161, revised, p. 19): "With the growing use of atomic energy for peaceful purposes, the full protection of workers who are injured on the job due to radiation hazards is of prime importance."

The International Association of Industrial Accident Boards and Commissions (IAIABC) has recommended several steps for the improvement of State workmen's compensation laws, particularly to cope with these new and expanded radiation hazards, including the following:

1. All State workmen's compensation laws should cover occupational diseases as well as industrial accidents. All States have basic legislation in this field; but two do not provide occupational disease coverage: Mississippi and Wyoming.

2. Where occupational disease laws do exist, they should be reviewed and, where necessary, revised to cover claims resulting from radiation hazards. Twenty-eight States, Alaska, the District of Columbia, and Hawaii (and the United States, in its coverage of Federal employees and longshoremen) provide full coverage of occupational diseases. Several additional States have specified coverage in their laws for certain diseases due to exposure to

radioactive substances and materials. There appear to be at least eight States, according to the Department of Labor survey mentioned above, which do not cover any injuries due to radiation—Alabama, Iowa, Maine, Mississippi, Montana, New Hampshire, Tennessee, and Wyoming.

3. To assure full worker coverage for radiation diseases, and in light of the delayed appearance nature of many of these diseases, the IAIABC suggests that the time limitations in filing claims should begin to run from the date on which the employee has knowledge of the nature of the disability and its relation to his job and until after disablement. The IAIABC suggests elimination of time limitations requiring the disease to occur within a certain period (usually from 4 months to a year) after the last exposure.

4. Other features suggested by the IAIABC for consideration by the States are: (*a*) provision of unlimited medical benefits, including rehabilitation, in radiation cases; (*b*) vesting jointly the State agency administering compensation laws and the State medical society with authority to designate attending physicians and hospitals and rehabilitation facilities in all radiation exposure cases; and (*c*) making radiation cases, upon establishment of multiple exposure, eligible for second injury fund benefits.

The committee on suggested State legislation is impressed by the evidences of need that exist for extensive review, reevaluation, and revision of State workmen's compensation legislation in many States. It is evident that much thought and action should be devoted to these matters during the next few years.

An examination of the literature and reports available to the committee does not reveal that satisfactory answers have been found to one question of great, perhaps of overriding, practical importance—the matter of proof of causal relationship between occupational hazard and injury, in the radiation field. As noted above, many diseases and injuries which can be radiation induced also can result from other causes. In the absence of a satisfactory answer to this question, the committee is unable at this time to recommend specific courses of action to the States. It has established a subcommittee to work with the Council of State Governments and other appropriate groups and agencies during the coming year in an effort to find helpful answers to this question. A basis for needed State action should result from such study.

(F) PUBLIC LIABILITY OF STATE AND LOCAL LICENSEES FOR ATOMIC INCIDENTS

Under an amendment to the Atomic Energy Act of 1954, adopted by the Congress in 1957 (Public Law 85–256), a Federal indemnity program was established for nuclear activities undertaken by licensees of the Atomic Energy Commission. The statute requires licensees authorized to operate nuclear reactors to maintain financial protection (in the form of nuclear energy liability insurance, resources of the licensee or in some other appropriate form) in an amount specified by the Atomic Energy Commission against public liability claims based on a nuclear incident arising out of the licensed activities. Above the amount of financial protection, the Atomic Energy Com-

mission provides indemnity protection in the amount of $500 million. The statute abolishes all legal liability in excess of the sum of $500 million plus the amount of financial protection required of the licensee.

After adoption of Public Law 85–256, it developed that a substantial number of State agencies which had applied for or possessed licenses from the Commission to operate nuclear reactors were unable to comply with the requirement that they furnish financial protection. As a result, the atomic energy law committee of the National Association of Attorneys General and the committee on suggested State legislation of the Council of State Governments undertook the preparation of draft State legislation designed to enable State and local agencies to comply with the financial protection requirements of the Atomic Energy Act.

In August 1958, Public Law 85–744 was enacted amending the legislation adopted the previous year. The 1958 amendment establishes an exemption from the financial protection requirements with respect to licenses issued for the conduct of educational activities to persons found by the Commission to be nonprofit educational institutions. Because it appears that the exemption contained in Public Law 85–744 is broad enough to include all State agencies which have applied for, or are likely to apply for, an AEC license for which financial protection is required, the text of the draft bill prepared by the aforementioned committees has not been included in this report. In the event, however, a situation arises where a State agency desires to obtain an AEC license for which financial protection is required, and the licensee is not included within the scope of the exemption granted by Public Law 85–744, the agency may wish to obtain a copy of the draft bill by writing to the Council of State Governments, 1313 East 60th Street, Chicago 37, Ill.

PART VII

SUGGESTED STATE LEGISLATION FOR 1959 ON WORKMEN'S COMPENSATION IN LIGHT OF RADIATION HAZARDS

REPORT AND RECOMMENDATIONS OF SUBCOMMITTEE ON WORKMEN'S COMPENSATION, COUNCIL OF STATE GOVERNMENTS, APPROVED BY COMMITTEE ON ATOMIC ENERGY LAW, NATIONAL ASSOCIATION OF ATTORNEYS GENERAL

WORKMEN'S COMPENSATION COVERAGE IN LIGHT OF RADIATION HAZARDS

The protection of workers exposed to radiation hazards presents problems, some of them unprecedented, under State workmen's compensation laws. With the recent rapid increase in the use of atomic energy for industrial, scientific, and research purposes, it has seemed highly desirable that these laws, as they relate to atomic energy and other forms of radiation, be reviewed and recommendations developed which might be brought to the attention of the States for consideration during 1959 legislative sessions.

Workmen's compensation laws are in effect infall States, the District of Columbia, Hawaii, and Puerto Rico. Very few of these laws

provide protection which is adequate in all respects for workers exposed to radiation hazards. The attached materials have been prepared to enable each State to compare its law with certain recommended workmen's compensation standards and thus to identify existing gaps or inadequacies. Suggested legislation is provided to assist States in revising their laws in accordance with recommended standards.

The chart which accompanies these proposals will give a quick picture as to the extent to which the workmen's compensation laws of the States and other jurisdictions provide protection for radiation injuries. The chart is limited to provisions in the laws and does not include information on judicial decisions or administrative interpretations, rules, and regulations. It is suggested that the laws should be specific with respect to the matters dealt with in the following so that the employer and worker are not required to rely on court interpretation.

The standards covered are based primarily on those recommended by the International Association of Industrial Accident Boards and Commissions (IAIABC). This organization is composed primarily of the administrators of the various State and Canadian provincial workmen's compensation agencies; associate memberships are maintained by medical and legal associations, insurance companies and associations, business and industrial concerns, AFL–CIO, law firms, and actuarial establishments. These standards also conform to those recommended by the American Medical Association, the American College of Surgeons, and other organizations and groups.

Although the purpose of these proposals is to call the attention of the States to workmen's compensation standards which have a special relationship to radiation injuries, the suggestions for legislation are not specifically limited to radiation injuries. Also it should be pointed out that these proposals do not purport to cover all aspects of workmen's compensation that should be considered. Other provisions including reciprocal arrangements for coverage, adequacy and duration of benefits, and administrative procedures are presently under study. The standards relating to coverage of employers do not affect the existing exemptions for specified workers such as farm or domestic workers. Nor do they deal with the problem of nonprofit organizations many of which are users of radioisotopes such as hospitals, colleges, and other research institutions. Neither do they affect the method of insurance or self-insurance which the employer is permitted to follow at present.

The legislation to carry out the suggested standards is based on tested experiences of the States. In general, the suggested provisions are similar to those already in effect in some of these laws or represent a composite of language in a number of such laws. Adjustments will be necessary, of course, to fit the language into a particular State law. In addition, the amendment of one section of the law may necessitate amendment of a number of other sections to accomplish the desired objective. In preparing amendments, therefore, a careful examination should be made of the entire law to assure that all pertinent sections are amended properly.

The term "injury" or "radiation injury," wherever used in these proposals, is intended to mean a work injury or disease which is compensable under the workmen's compensation law or for which

the worker is entitled to medical aid under the workmen's compensation law. The term does not necessarily refer to the medical definition of injury.

In the discussion of the various workmen's compensation laws, the use of the term "State" also includes the District of Columbia, Hawaii, and Puerto Rico.

A. COMPULSORY LAWS

It is suggested that all workmen's compensation laws be compulsory rather than elective.

Workmen's compensation laws may be classified as compulsory or elective.

A compulsory law requires every employer within the coverage of the act to accept its provisions and to provide for the benefits prescribed by the act. About one-half of the workmen's compensation laws in this country are compulsory.

An elective law permits the employer and employee to accept or reject the provisions of the law. Under most types of elective laws, acceptance of the act by the employers or employees is presumed unless specific notice of rejection is filed. If the employer rejects the law, he loses the customary common law defenses of assumed risk of employment, negligence of fellow servants, and contributory negligence. If the employee rejects the act but the employer accepts it, then the employer is allowed to use the common law defenses in case of a suit by the employee for damages. If an employer has rejected the act, his employees may be unable to obtain compensation unless they sue for damages regardless of whether or not they have accepted the act.

The first test, therefore, of whether a workmen's compensation law covers radiation injuries is the type of law. If elective, an injury may or may not be covered. For various reasons it is particularly important that a State workmen's compensation law cover radiation injuries. A radiation injury may show up years after the exposure which was its cause. A causal relationship may be difficult or impossible to prove because witnesses have disappeared, the employer may have gone out of business, or, in the event negligence is charged, the statute of limitations respecting any action for negligence may have run. On the other hand, if only radiation industries are compelled to have workmen's compensation, discrimination in awards to injured workers between or within industries or even within one business may result.

Suggested Legislation[1]

Sec. —. The following shall constitute employers subject to the provisions of this act:

(*a*) Every person, partnership, firm, association, trust, corporation or legal representative thereof, that has in service one or more employees.

(*b*) The State, county, city, town, township, incorporated village, school district, sewer district, drainage district, public or quasi-public corporation, or any other political subdivision of the State that has in service one or more employees or officials.

[1] In considering this suggested language it will be necessary to make certain that the series in (*a*) and (*b*) follow the terminology customary in a specific State and that all sections of the act be in conformity.

B. NO NUMERICAL EXEMPTION

It is suggested that the workmen's compensation law apply to all employers subject to the act regardless of the number of employees.

The effectiveness of workmen's compensation laws is limited in many States by numerical exemptions under which employers with fewer than a specified number of employees are not covered by the law. The laws in 23 States make no exemption based on number of employees. In 29, however, employers of less than a certain number of employees are exempt from coverage. This numerical exemption ranges from 2 employees to 15.

Radioisotope users frequently involve employers with only a few employees. It is expected that the use of radioisotopes by small employers will increase greatly. It is important, therefore, that the numerical exemption be removed.

Workers employed by employers who have only a few employees are usually particularly in need of the protection offered by the workmen's compensation laws. The small establishment is more likely to lack an organized accident-prevention program and the financial resources to take care of the injured workers in case of serious injury. At the same time, the employer in a small business establishment also needs workmen's compensation to protect himself against lawsuits for damages brought by employees injured in his establishment.

Suggested Action

No specific provision is suggested for this purpose since it would involve mainly the repeal of the present section or clause establishing the numerical exemption and substituting therefor the words "one or more employees." [2]

C. RECIPROCAL ARRANGEMENTS FOR EXTRATERRITORIAL COVERAGE

The extent of coverage of radiation injuries also is affected by the extraterritorial provisions of the various workmen's compensation laws. When an employee hired in one State is injured in another, sometimes he is covered by the law of the State where he was hired, sometimes such coverage is doubtful, depending upon a number of factors. On the other hand, sometimes the employee is specifically covered by the law of the State where the injury occurred. In many instances it is difficult to determine in what State the remedy should be sought. The difficulty is caused by the varying provisions of the different laws relating to this problem.

Some of the States, including Connecticut, Massachusetts, and Ohio, provide, with no restrictions, that the law covers resident workers of the State for injuries occurring both within the State and outside the State, regardless of whether the employment contract was made within the State or outside the State. Others provide that if a contract to work is made in the State, the law will apply in cases of injuries outside the State.

Still others—for instance, those of California, Michigan, and Nevada—require that the employee's regular place of employment,

[2] Note suggested legislation in "A. Compulsory Laws."

or the employee's residence, or both, also be in the State where the contract is made. Some of the laws also require that the accident must occur within a certain time after leaving the State; for instance, Texas sets 1 year, and Colorado and Utah set 6 months. Delaware and Pennsylvania specify that the work outside the State must not extend beyond a period of 90 days. About one-fourth of the laws omit any reference to extraterritoriality, but the courts of some of these States, for instance those of New Jersey and New York, have interpreted the law as being applicable to such accidents. The New York law has been held to apply if the contract of employment was made in the State, or the employment was incidental to a business carried on in the State. The New Jersey law has been construed to apply generally to accidents incurred in the State on contracts of hire made outside the State.

In 11 States reciprocal arrangements have been developed to meet this problem. Under these arrangements, the workmen's compensation law may not apply to an employee temporarily within the State if his employer has furnished proof of workmen's compensation coverage under the law of another State and provided that the other State also recognizes the same extraterritorial application for employees temporarily within its borders. Seven of these laws provide specifically for such reciprocal arrangements. In the other four laws, the workmen's compensation agency is authorized to enter into reciprocal agreements with other States.

The 1958 Western Regional Conference of the Council of State Governments adopted a resolution memorializing the legislatures of the Western States, which have not already done so, to enact specific extraterritorial coverage on a reciprocal basis.

Extraterritorial provisions will affect the coverage of radiation injuries primarily for workers engaged in the installation, construction, and servicing of atomic energy facilities, radiography and testing, research, and in the transportation of materials with a radiation hazard where such workers cross State lines. No recommendation or suggested language is included on this item pending further consideration by the committee on suggested State legislation.

D. WAIVERS PROHIBITED

It is suggested that workmen's compensation laws specifically prohibit waivers.

Most jurisdictions prohibit a covered employee from waiving his rights to compensation. However, early in the history of workmen's compensation, a number of States enacted provisions permitting handicapped workers to waive their rights to benefits for an injury caused, or contributed to, by a previous disability. This was done because of the reluctance of employers to hire or keep an employee whose physical condition might create an extra compensation cost if he suffered a further injury on the job.

The development of the second or subsequent injury fund system has made the need for waiver provisions obsolete. However, some jurisdictions still authorize the use of waivers. The elimination of the use of waivers is particularly desirable in view of the delayed manifestation and other characteristics of radiation injuries.

SUGGESTED LEGISLATION

SEC. —. No agreement by an employee to waive his right to compensation under this Act shall be valid.

E. FULL COVERAGE OF OCCUPATIONAL DISEASES

It is suggested that full coverage of occupational diseases be provided.

The rapidly expanding use of atomic energy for industrial purposes makes it imperative that the workmen's compensation law protect a worker who is exposed to ionizing radiation. To achieve this protection, occupational disease coverage of many of the laws must be extended. The laws of the States range from no coverage of occupational diseases (Mississippi, Montana, and Wyoming) to full coverage of any disease that is caused by the employment. Consideration must be given to the workmen's compensation laws which do not provide for any occupational disease coverage or which partially cover occupational diseases by the so-called schedule method. States with scheduled coverage should examine their laws and particularly the definitions of radiation coverage. It is doubtful if a definition such as "radium poisoning or injury by X-rays" would include injuries resulting from use of atomic energy. Another definition sometimes used, such as "ulceration of the skin or destruction of tissue due to the prolonged exposure to roentgen rays or radium emanations," also presents problems. For example, what is "destruction of tissue"? What is meant by "prolonged" exposure?

The International Association of Industrial Accident Boards and Commissions has recognized this problem and its 1956 atomic energy committee recommended the following language: [3]

It is suggested that a uniform language be used and that the term "disease caused by exposure to ionizing radiation" be inserted in the law where considered necessary.

Forty-one laws provide some coverage for diseases caused by ionizing radiation. This includes the 31 States which provide for complete coverage of all occupational diseases, either by definition or by adding a catchall provision to a schedule listing of diseases. In the other States coverage is restricted to the specific diseases listed in the law, but in 10 of these the scheduled coverage appears to be quite adequate as regards radiation injuries.

Two methods of providing full coverage are suggested:

(1) For those States which have scheduled coverage of occupational diseases and wish to retain this method of coverage it is suggested that the schedule include the following provisions to assure full coverage:

SUGGESTED LEGISLATION

SEC. —. Any disease caused by exposure to ionizing radiation from sources inside or outside the body.

SEC. —. All other occupational diseases.

(2) For those States which do not have any coverage of occupational diseases in their law, or those which wish to eliminate the scheduled coverage and achieve full coverage by definition of injury, it is suggested that the following provision be considered:

[3] "Workmen's Compensation Problems," Bull. 192, Bureau of Labor Standards, U.S. Department of Labor, p. 165.

SUGGESTED LEGISLATION

SEC. —. "Injury" means mental or physical harm, including disease or infection to an employee and damage to or loss of an employee's prosthetic appliances, arising out of employment.

F. TIME LIMIT FOR FILING CLAIM IN OCCUPATIONAL DISEASE CASES BASED ON DATE OF WORKER'S KNOWLEDGE AND DATE OF DISABLEMENT

It is recommended that a flexible time-limit provision be provided in order that the workmen's compensation law extend protection to a worker suffering from an ionizing radiation disease resulting from his employment.

One of the major problems affecting the coverage of slowly developing diseases is the requirement regarding the time in which a claim must be filed. Many of the laws require that the claim be filed within a certain period after date of last exposure. Other laws require that the time for filing a claim be based on the date of disablement regardless of whether or not the worker knows the cause of disablement. A few States use the date of manifestation of symptoms as the date from which the time begins to run.

A worker may not know that he is suffering from a radiation disease for many years after the date of last exposure. It may be 10, 20 or more years after exposure before a worker becomes disabled and has a knowledge that the condition requiring treatment is directly related to his radiation exposure while on the job. To protect the worker in such cases, it is necessary, therefore, to base the time limit on date of his knowledge of the nature of his disease and its relation to his job. A worker may not realize, until after he becomes disabled, that a workmen's compensation claim must be filed in order to receive the benefits of that law. For this reason it is important to include both date of disablement *and* date of worker's knowledge of cause of disablement to assure that the worker is fully protected.

The 1956 Atomic Energy Committee of the International Association of Industrial Accident Boards and Commissions (IAIABC) recommended the following time limit standard for filing claims in radiation injury cases: [4]

> * * * To assure full protection of the worker in such cases, it is suggested that requirements that exposure occur within a specified period be eliminated and the time limitation in filing of claims not begin to run until *the date on which the employee has knowledge of the nature of his disability and its relation to his job and until after disablement. It is suggested that the time limit should be at least 1 year after such date.*

The suggested legislation should appear as a supplement to existing statutory provisions dealing with time periods within which workmen's compensation claims must be filed.

SUGGESTED LEGISLATION

SEC. —. The time for filing claims shall not begin to run in cases of latent or undiscovered physical or mental impairment due to injury (including disease) until (1) the person claiming benefits knew, or by exercise of reasonable diligence should have known, of the existence of such impairment and its causal relationship to his employment or (2) after disablement, whichever is later, *Provided*, That in any such case in which indemnity benefits have been paid, the claimant's right to compensation is preserved without time limitation.

[4] "Workmen's Compensation Problems," Bull. 192, Bureau of Labor Standards, U.S. Department of Labor, p. 165.

G. UNLIMITED MEDICAL BENEFITS

It is suggested that full medical benefits for both accidental injuries and occupational diseases be provided by law.

Every State workmen's compensation law provides for medical aid to an injured worker. The laws, however, vary from State to State as to the extent of such care. Fourteen of the laws provide complete medical care for accidental injuries or occupational diseases. Fifteen other laws place a limitation of time or amount on medical benefits but authorize the administrative agency to extend such benefits beyond the initial maximum stated in the law. The remainder of the laws limit medical aid either by period of time or cost limitations or both.

Radiation injuries or diseases because of their nature are particularly likely to involve extensive medical care. There is evidence to show that radiation injuries or diseases after apparent recovery may recur and again require medical care. It is important, therefore, that the laws provide full medical benefits.

SUGGESTED LEGISLATION

SEC. —. The employer shall furnish such medical, surgical and medical rehabilitation services, and other attendance or treatment, nurse and hospital service, medicine, prosthetic appliances and proper fitting and training in the use of such appliances, for such period as the nature of the injury (including disease) may require and as necessary to restore the employee to his maximum level of physical capacity and to give relief from pain. The employer shall also furnish replacements or repairs of such prosthetic appliances when deemed necessary by the [Workmen's Compensation Agency], unless the need for such replacements or repairs is due to lack of proper care by the employee, or unless the injury consists solely of loss of or damage to a prosthetic appliance and adequate replacement or repair has been made by the employer.

H. AUTHORITY FOR WORKMEN'S COMPENSATION AGENCY TO SUPERVISE MEDICAL CARE

It is suggested that the workmen's compensation agency have the authority to supervise and order changes in medical care so that specialized treatment may be given in all cases where it is deemed to be necessary.

Radiation cases will often require specialized treatment. For this reason it is important that workmen's compensation agencies have the authority to supervise and control medical care.

The Medical Committee of the International Association of Industrial Accident Boards and Commissions (IAIABC) in 1956 formulated a set of principles which included the following:[5]

This association recognizes that the ultimate aim of the compensation process is to return an injured workman to a job as quickly as possible with a minimum of permanent disability. In order to achieve this objective the administrative agency must be given responsibility by statute to supervise and control medical care. This principle is now recognized by the American College of Surgeons and the American Medical Association through the Council on Industrial Health. The commission should supervise medical care with a view to determining the accuracy of diagnosis from the outset until final determination. It is recognized that this grave responsibility will be shared with appropriate medical advisory bodies.

[5] "Workmen's Compensation Problems" (Bull. 102), Bureau of Labor Standards, U.S. Department of Labor, p. 247.

The 1957 committee of this same organization indicated that only two States approached the recommended standard as it relates to supervision of medical care. The standard as prescribed by the IAIABC includes the following: [6]

1. One or more physicians on staff of workmen's compensation agency.
2. Reports required by the workmen's compensation agency from attending physicians.
3. Right of workmen's compensation agency to suggest to attending physician the need for change in treatment.
4. Use of impartial advisory medical panels to supervise medical care.

To achieve this standard, the law should be amended where necessary.

SUGGESTED LEGISLATION

SEC. —. The [head of workmen's compensation agency], on competent medical advice, shall have authority to determine the necessity, character, and sufficiency of any medical or medical rehabilitation aid furnished or to be furnished and shall have authority to order a change of physician, hospital, or rehabilitation facility when such change is determined to be desirable or necessary.

I. BROAD TYPE COVERAGE SECOND OR SUBSEQUENT INJURY FUNDS

It is recommended that a second or subsequent injury fund cover all types of permanent physical impairments that are likely to be a hindrance or obstacle to employment.

The second or subsequent injury fund served to reduce the fear of employers that they may be assessed a heavy compensation cost if the handicapped worker suffers a subsequent injury. To meet this problem subsequent injury funds have been established in all but five States (Georgia, Louisiana, Nevada, New Mexico, and Virginia).

A subsequent injury fund is a special fund to insure that an employer who hires a handicapped worker will not, in the event such worker suffers a subsequent injury on the job, be responsible for the payment of compensation for a greater disability than that actually resulting from the subsequent injury by itself. Under the New York and Minnesota laws, the employer is only liable for compensation for a maximum of 104 weeks. But the employee is fully compensated. The subsequent injury fund pays the difference between what the injured worker receives from the employer and what the law provides for the actual disability resulting from the combined injuries.

Existing second or subsequent injury fund provisions of State workmen's compensation laws may provide for coverage of any type of prior disability—such as polio, epilepsy, arthritis, heart disease, or diabetes; or it may be so limited that it applies only to such handicaps as the loss, or loss of use, of a hand, arm, foot, leg, or eye. The great majority of these funds are limited in coverage to the loss of a member of the body.

A worker who has suffered a radiation injury may find it difficult to retain his present job or to obtain other employment where a subsequent injury fund does not cover such injuries. Less than one-third of the laws have subsequent injury funds that cover radiation injuries.

[6] "Workmen's Compensation Problems" (Bull. 195), Bureau of Labor Standards, U.S. Department of Labor, pp. 172-173.

As to the methods of financing such funds, the International Association of Industrial Accident Boards and Commissions (IAIABC) Second Injury Fund Subcommittee reported in1958 as follows:

Where a broad coverage is provided, based on the first injury resulting from a nonindustrial traumatic injury or a congenital condition, the liability for financing of the second injury fund should be shared by industry and society at large. In other words, where a preexisting condition is the result of a nonoccupational accident or disease the State should be required to contribute its proportion of the cost of the case thus reducing the cost to the employer. It is believed that by so relieving the employer from the entire cost of all second injury cases, the employment of handicapped persons will be encouraged.

This committee also suggested:

The limitation of the medical liability of the employer in second injury cases to a specific amount with the balance payable by the second injury fund is a further consideration to encourage the employment of the handicapped.

Section 1 of the suggested legislation is designed to make it possible for a State to cover radiation injuries under its currently existing second injury fund. Section 2 suggests a possible method a State might use to finance a second injury fund where none exists or where a State contemplates changing its present method of financing.

SUGGESTED LEGISLATION

[Title should conform to State requirements]

(*Be it enacted, etc.*)

SEC. 1. Whenever an employee who has a permanent physical impairment due to previous accident or disease or any congenital condition, which is or is likely to be a hindrance or obstacle to his employment, incurs a subsequent disability by reason of a personal injury, for which compensation is required by this Act, resulting in permanent partial or permanent total disability that is substantially greater by reason of the combined effects of the impairment and subsequent injury than that which would have resulted from the subsequent injury alone, the employer or his insurance carrier shall in the first instance pay all awards of compensation provided by this Act, but such employer or his insurance carrier shall be reimbursed by the State treasurer from the fund created by section 2 for all compensation subsequent to that payable for the first one hundred and four weeks of disability and for all medical benefits in excess of $1,500.

If the subsequent injury of such an employee shall result in the death of the employee, and it shall be determined that either the injury or the death would not have occurred except for such preexisting permanent physical impairment, the employer or his insurance carrier shall in the first instance pay the compensation prescribed by this Act, but he or his insurance carrier shall be reimbursed by the State treasurer from the fund created by section 2 for all compensation payable in excess of one hundred and four weeks and for all medical benefits in excess of $1,500.

The word "compensation" as used in this section for the purpose of reimbursement means all payments to the injured worker or to his dependents in case of death, and payments for medical, hospital, burial, and other services, made under the provisions of this chapter.

SEC. 2. There is hereby established in the State treasury a special fund for the purpose of making payments for subsequent injury in accordance with the provisions of section 1. Such fund shall be administered by the workmen's compensation agency. The State treasurer shall be the custodian of such fund and all moneys and securities in such fund shall be held in trust by such treasurer and shall not be the money or property of the State.

(A) The treasurer is authorized to disburse moneys from such fund only upon order of the workmen's compensation agency. He shall be required to give bond in an amount to be fixed and with the securities approved by the workmen's compensation agency conditioned upon the faithful performance of his duty as a custodian of such fund. The premium of such bond shall be paid out of such fund.

(B) Two separate accounts shall be established under the special fund created under this section. One account shall be designated item A. The other shall be designated item B.

(1) Payments shall be made into item A of the special fund as follows:

(a) The State legislature shall appropriate an amount necessary to meet the payments provided under this section from item A of the special fund.

(2) Payments shall be made into item B of the special fund as follows:

(a) Each employer shall pay $2,000 as indemnity benefits for the death of an employee of such employer resulting from injury where the workmen's compensation agency determines that there is no person entitled under this title to indemnity benefits for such death. Whether there is such a person shall be ascertained as of the time of the determination.

(b) Each insurance carrier shall annually under regulations prescribed by the workmen's compensation agency make payments to such fund in an amount equal to 1 per centum of the gross premium received from workmen's compensation insurance written or renewed by it during the preceding calendar year on risks within this State or subject to the jurisdiction of this State.

(c) Each self-insurer shall annually, under regulations prescribed by the workmen's compensation agency, make payments to such fund in an amount equal to 1 per centum of the premium which such employer would have had to pay to obtain workmen's compensation insurance for the preceding calendar year (or proportional year if a self-insurer has not been authorized for the full year), which amount shall be determined by the workmen's compensation agency.

(C) Payments from items A and B shall be made as follows:

(1) Item A shall be used to reimburse employers or insurance carriers for all payments due under this section to any employee whose prior permanent physical impairment was not incurred as the result of an employment injury.

(2) Item B shall be used to reimburse employers or insurance carriers for all payments due under this section to any employee whose prior permanent physical impairment was incurred as the result of an employment injury.

J. MAINTENANCE BENEFITS DURING REHABILITATION

It is recommended that special maintenance benefits be provided during the period of rehabilitation.

Less than half of the State workmen's compensation laws contain any specific provision on rehabilitation of workers. A worker with a disabling injury or one who has suffered excessive exposure while on the job, such as exposure to ionizing radiation, silica dust, or noise, may be precluded from working at his former or similar employment. Rehabilitation and retraining for another job may be needed in such cases. The extent to which a worker will be entitled to rehabilitation services will be determined by the particular workmen's compensation law involved. About one-third of the States provide for special maintenance or other compensation to facilitate the rehabilitation of workers.

Workmen's compensation agencies have a special responsibility with respect to the rehabilitation of the worker who is injured in the course of his employment or who has received an excessive exposure which necessitates a change in his employment. They are the first State agencies to know about these cases and are thus in a position to promote the rehabilitation of the worker. Unless rehabilitation begins soon after the injury, maximum physical restoration may not be possible.

In order to facilitate the acceptance of rehabilitation by the worker and thus reduce the extent of his disability, or in order to enable him to be trained for other employment because of excessive exposure, it is suggested that special rehabilitation benefits be provided to cover his additional expenses and to help offset his loss of income during the rehabilitation period.

Suggested Legislation

Sec. —. In addition to the benefits provided elsewhere in this Act, the employee shall be entitled to (1) such vocational rehabilitation services, including retraining or job placement, as may be necessary to restore him to suitable employment; (2) such additional compensation as may, in the discretion of the (Agency) be deemed necessary for his board, lodging, travel, and other expenses and for the maintenance of his family during the period of rehabilitation at a rate not to exceed the maximum weekly benefit established under section —.[7] The (Agency) shall have the duty of determining whether an employee needs vocational rehabilitation services and shall cooperate with, and refer promptly all cases in need of such services to the appropriate public or private agencies in the State, or where necessary, in any other State, for such services. The (Agency) under regulations adopted by the (Agency) shall reimburse such agencies for the cost of such services and shall pay for maintenance and other expenses out of the special fund established under section —.

Extent of protection under State workmen's compensation laws for workers exposed to radiation hazards

[X indicates law meets recommended standard; — indicates law does not meet standard]

	Compulsory law (a)	No numerical exemption (b)	Reciprocal arrangements for extra-territorial coverage (c)	Waivers prohibited (d)	Full coverage of occupational diseases (e)	Time limit for filing claim in occupational disease cases based on date of worker's knowledge and date of disablement (f)	Unlimited medical benefits (g)	Authority for workmen's compensation agency to supervise medical care (h)	Broad type coverage under 2d or subsequent injury fund (i)	Maintenance benefits during rehabilitation (j)
Alabama	—	—	—	(2)	—	—	—	—	—	—
Alaska	X	X	—	X	X	—	—	—	X	X
Arizona	X [8]	—	—	X	(4)	—	—	X	—	X
Arkansas	X	(5)	—	—	X	—	—	X	—	X
California	X	X	X	X	X	X	X	—	X	—
Colorado	—	—	(6)	—	(7)	—	—	X	—	—
Connecticut	—	—	—	—	X	—	—	X	—	—
Delaware	X	—	—	X	X	—	X	X	X	—
District of Columbia	X	X	—	X	X	—	X	—	X	X
Florida	—	—	—	X	X	—	(9)	X	X	—
Georgia	—	—	—	—	(7)	—	—	X	—	—
Hawaii	X	X	—	X	X	—	X	X	X	X
Idaho	X	X	—	—	(3)	—	X	X	—	—
Illinois	X	X	—	(3)	X	—	—	X	—	—
Indiana	(10)	X	—	—	X	—	(3)	X	—	—
Iowa	(10)	X	—	—	—	—	—	—	—	—
Kansas	—	(11)	—	—	(7)	—	—	X	—	—
Kentucky	—	—	—	X	X	—	—	X	—	—
Louisiana	—	X	—	X	(7)	—	—	—	—	—
Maine	—	—	—	(3)	—	—	—	—	—	—
Maryland	X	X	—	—	X	—	—	—	—	—
Massachusetts	X	—	—	—	X	—	(3)	—	—	X
Michigan	X	—	—	X	X	—	X	—	—	—
Minnesota	X	X	—	—	X	—	—	—	—	—
Mississippi	X	—	X	—	—	—	X	X	X	X
Missouri	—	(12)	—	X	X	—	(3)	X	X	X
Montana	(10)	X	—	X	—	—	—	X	—	—
Nebraska	—	X	—	X	X	—	X	X	—	—
Nevada	X	—	—	—	X	—	—	X	—	—
New Hampshire	X [8]	—	—	—	—	—	(3)	—	—	—
New Jersey	—	X	—	X	X	—	(3)	—	X	—
New Mexico	—	—	(6)	—	(7)	—	—	—	—	—
New York	X	(13)	—	X	X	X	X	—	X	X
North Carolina	—	—	—	—	(4)	—	(9)	X	—	—

See footnotes at end of table, p. 230.

[7] The maximum weekly rate provided by the Act for temporary total disability.

Extent of protection under State workmen's compensation laws for workers exposed to radiation hazards—Continued

	Compulsory law (a)	No numerical exemption (b)	Reciprocal arrangements for extra-territorial coverage (c)	Waivers prohibited (d)	Full coverage of occupational diseases (e)	Time limit for filing claim in occupational disease cases based on date of worker's knowledge and date of disablement (f)	Unlimited medical benefits (g)	Authority for workmen's compensation agency to supervise medical care [1] (h)	Broad type coverage under 21 or subsequent injury fund (i)	Maintenance benefits during rehabilitation (j)
North Dakota	X	X	X	X	X	—	X	X	—	X
Ohio	X	—	—	—	X	—	[2]	[14]	—	X
Oklahoma	X	—	—	—	[3]	—	[2]	—	—	—
Oregon	—	X	X	X	X	—	[2]	X	—	X
Pennsylvania	—	X	—	X	X	—	[2]	X	—	—
Puerto Rico	X	X	—	[9]	X	—	X	X	X	—
Rhode Island	X	—	X	X	X	—	[2]	—	—	—
South Carolina	—	—	—	—	X	—	[2]	X	—	—
South Dakota	—	X	X	—	[5]	—	—	—	—	—
Tennessee	—	—	—	—	—	—	—	—	—	—
Texas	[15]	—	—	—	[3]	—	—	X	—	—
Utah	X	X	[6]	X	X	—	—	X	—	X
Vermont	—	—	—	—	[7]	—	—	—	—	—
Virginia	X	—	—	—	[7]	—	—	X	—	—
Washington	X	X	—	X	X	—	X	X	X	—
West Virginia	—	X	—	X	X	—	—	—	X	X
Wisconsin	X	—	—	—	X	—	X	X	X	X
Wyoming	X	X	[6]	X	—	—	—	—	—	—

[1] Based on whether workmen's compensation agency has authority to order change in treating physician.
[2] No provision in the law, waivers not permitted in practice, according to the State workmen's compensation agency.
[3] Employee may reject coverage under the act.
[4] Scheduled coverage—very limited for radiation diseases.
[5] Contractor engaged in building or building-repair work is covered if he employs 2 or more employees at any one time. If contractor subcontracts any portion of work, contractor is covered if either the contractor or subcontractor has only 1 employee.
[6] Not specifically provided in law but authorizes workmen's compensation agency to make such arrangements with other States.
[7] Scheduled coverage including radiation diseases.
[8] Law limits period or amount but authorizes administrative agency to extend without limit.
[9] Waivers can be granted but according to the workmen's compensation agency, waivers have not at any time been permitted.
[10] Compulsory only as to coal mining.
[11] Numerical exemption does not apply to employment in mines and building construction.
[12] If Workmen's Compensation Commission determines that employer of 10 or less employees is engaged in hazardous employment, such employer shall be covered unless he rejects coverage under the act within 10 days.
[13] Numerical exemption applies only in cases of nonhazardous employments. However, the 14 groups of hazardous industries are so comprehensive that the numerical exemption seldom applies.
[14] Employee has initial free choice of doctor but industrial commission may order change by giving employee right to choose from a panel of at least 3 doctors chosen by industrial commission.
[15] Compulsory as to motorbus companies.

PART VIII

REPORT OF ATOMIC ENERGY COMMITTEE, INTERNATIONAL ASSOCIATION OF INDUSTRIAL ACCIDENT BOARDS AND COMMISSIONS

Forty-fourth annual convention, Seattle, Wash., September 9, 1958—Ned J. Parsekian, chairman, John F. Cauley, John Moulin, George Roche, Clay Shackelford, Willis Weeden, M.D.

There can be little doubt that most workmen's compensation jurisdictions represented at this convention, today provide totally inadequate protection for workers against radiation hazards. The report

just received by this convention on the subject of the present status of the workmen's compensation laws with respect to protection against and exposure to radiation, places in bold relief the fragile protection offered industrial workers who toil in the vanguard of the bold atomic era.

At its 1956 convention this organization recommended that States adopt workmen's compensation legislation providing for:

1. Examination and inspection of plants to determine the type and quantity of radiation present in work areas.
2. Unlimited medical care.
3. Supervision of medical care.
4. Full coverage of occupational disease.
5. Statutory time limitation on claims to run from the date on which the employee has knowledge of the nature of his disability and its relationship to his employment.

At the 1957 convention the atomic energy committee of this organization reported that "the recommendations made in 1956 have, almost without exception, been ignored."

While over the years scientific and industrial development of nuclear energy has been marked by dynamic growth, governmental development of safety standards and workmen's compensation protection has been marked by inaction.

The atomic energy committee of this organization in 1956 reported 30 civilian nuclear reactors in use in the United States. As of June 30, 1958, the U.S. Atomic Energy Commission reported 175 civilian nuclear reactors in operation or under construction, an increase of over 500 percent in a 2-year period. It is reported furthermore that 67 additional reactors are in the planning stage.

The total of radioisotope licenses outstanding as of May 31, 1958, was 3,750 of which 1,744, or 45 percent, were issued in the prior 18 months. The growth exceeds even that indicated by the sharp rise in the number of licenses issued, for, since 1954 uses of radioisotopes have been authorized under general licenses which permit the possession and use of specified limited quantities of 65 assorted radioisotopes. Theretofore, each license was limited to a specific isotope.

Measured another way, the quantity of radioisotope shipments by the atomic energy committee in terms of radio activity for the 10-year period 1946–56, totaled 219,197 curies as compared to shipments for the 16-month period January 1957 through May 1958, of 236,988 curies. This represents an increase in monthly rate of use of over 1,000 percent. It is predicted that the growth during the next decade will outstrip the geometric growth of the decade just ended.

That the problems of safety and workmen's compensation coverage in this new industry are national in scope, is attested to by the fact that there are five or more licensed users in every State in the country. That the problem will affect States presently regarded as nonindustrial, is appreciated when we consider that industrial production is now released from geographic ties to traditional sources of energy; water, oil, and coal. The few pounds of source material for nuclear energy required to sustain heavy industrial production can be easily and rapidly transported to any State.

The introduction of nuclear energy has shattered once accepted basic principles of science. The introduction of nuclear energy as a

34434—59——16

corollary has shattered basic accepted principles of workmen's compensation.

The concept that matter and energy could neither be created, destroyed nor transformed was challenged in 1905 when Einstein suggested that energy and mass are equitable and alterable quantities. His formula suggested that a gram of mass could be transformed into an incredible amount of energy which defied the imagination, 900 billion billion ergs.

In January 1939 the theory was proved when scientists bombarded uranium with neutrons, producing barium and krypton and releasing tremendous energy as a byproduct. Man had split the atom.

The process of nuclear fission is accompanied by radioactive emissions, of which there are three major forms:

Alpha particles.—These are positively charged particles consisting of two protons and two neutrons which travel at an initial speed of 6,000 miles a second through a limited distance, however, of only 2 inches through air. Alpha particles can be shielded with a few layers of paper.

Beta particles.—These are electrons, negatively charged particles, emitted from the nucleus of the radioactive atom. Beta particles travel several feet in air and can be shielded by a thin sheet of aluminum.

Gamma rays.—A powerful wave of energy similar to the X-ray which can be shielded only by thick layers of lead or heavy concrete. Wherever atoms are fissioned exists potential of horrendous physical injury and genetic deterioration. Radioactive rays not only tear electrons out of inorganic matter through which they pass, but out of organic matter, human tissue, resulting in temporary or permanent damage to the cells of the skin, organs, blood or bones.

Its presently known effects include:

1. Ulcers of the skin.
2. Cancer of the skin, blood, lungs, other organs, and bone.
3. The formation of cataracts in the lens of the eye.
4. Premature aging, and shortening of life span
5. Genetic effects producing mutations
6. Skin irritation erythema, dizziness and vomiting

Each year additional industrial and medical uses for radioisotopes are discovered, multiplying the potential of these afflictions. Today industrial uses include:

1. Byproduct power
2. Process heat
3. Space heat
4. Land propulsion
5. Crop storage
6. Blight control
7. Deinfestation of products
8. Distillation of sea water
9. Food preservation
10. Blast furnace study
11. Determination of cigarette quantity and density
12. Location of obstruction in pneumatic tubes
13. Crankshaft inspection
14. Wear and abrasion measurements of all kinds

15. Measurement and control of thickness in rolling steel, linoleum, and other products
16. Determination of corrosion in high pressure steam lines, gas mains, and acid tanks
17. Density gages
18. Vacuum gages
19. Static eliminators
20. Safety controls
21. Location of oil holes and other outlets in metals and other dense products
22. Regulation and measurement of flow of both liquid and solid materials
23. Detection of gasket leaks and other defects
24. Catalytic and other application to solids
25. Radiographic detection of voids, flaws, and defects in welds, forgings, castings and solid products of all kinds

The uses of nuclear energy and radioisotopes continue to develop rapidly.

That the social problems of nuclear energy are national in scope was early recognized by the Federal Government. From 1940 to 1946 the research and development of nuclear fission was monopolized and financed exclusively by the executive branch of the Federal Government through the Manhattan District of the United States Army. The Atomic Energy Act of 1946 placed the development of nuclear energy under the civilian control of the Atomic Energy Commission. The AEC was authorized to enter into agreements with private contractors who would operate Government-owned production facilities. In addition, contracts and agreements with private universities and corporations were authorized to encourage research to permit private contractors to produce fissionable material for research purposes. Finally the AEC was permitted to distribute certain fissionable materials and radioactive isotopes to private persons or organizations for use in research and development.

Congress charged the AEC with concern for the safety of persons exposed to radiation. The act required the AEC to:

> Establish by regulation or order such standards and instructions to govern the possessions and use of fissionable and byproduct materials as the Commission may deem necessary or desirable to protect health or to minimize danger from explosions and other hazards to life or property.

The AEC was authorized, in addition, to cease further distributions or recall prior distributions from persons not adhering to safety standards it established. The 1946 act was void of language which would indicate encouragement of State regulation as to industrial safety or workmen's compensation coverage.

The Atomic Energy Act of 1954 broadened considerably the participation of private enterprise in nuclear research and in the use of radioisotopes for industrial purposes. Private ownership and operation of facilities for production of fissionable materials was authorized although, significantly, the statutory authority of the AEC to regulate safety aspects of such production was retained. The statutory authority of the AEC to set standards for the protection of life and property was reenacted with additional emphasis. The role of the States in industrial safety and workmen's compensation regulation

was not considered in the Atomic Energy Act of 1954, leaving open the question of jurisdiction.

On July 11, 1955 the AEC released Bulletin No. 660 noticing proposed standards for protection against radiation. These standards were made effective on February 28, 1957, and were based upon recommendations of the National Committee on Radiation Protection and Measurements.[1] The adoption of these regulations has not resulted in uniformity of safety standards. Although the AEC provides safety inspectors who presumably are to police radiation facilities, their effectiveness can be measured by the fact that as of July 1957 only four inspectors manned the so-called New York operation which covered part of New York, all of New Jersey, all of Pennsylvania and all of Connecticut, an area which included 1,280 licensees spread across an area of over 80,000 square miles. Nor have these regulations in anywise attempted to suggest minimum standards of workmen's compensation. As was reported to this Convention in an earlier report this morning, only one State has a schedule covering all possible radiation hazards, only 15 States give full medical benefits. Few States have a provision for limitation of time within which the action must be commenced and notice given to the employer which takes cognizance of the fact that manifestation of radiation injury may remain latent for as long as 30 years from date of exposure.

Even those States which have issued comprehensive regulations vary significantly from the standards set by the National Committee on Radiation Protection:[2]

1. They do not translate rads into rems, the units used in the NCRP and Federal regulations.

2. Maximum concentrations of radioactive substances in air do not vary with each radioisotope as in the NCRP standards.

3. The NCRP exceptions to maximum doses are not included and there are no separate maxima for local exposure as distinguished from whole body exposure.

4. Registration of users, which is regarded justifiably by the NCRP as a necessary prelude to effective regulation, appears not to be required.

5. Monitoring requirements are vague; locations are to be inspected "at scheduled intervals." No explicit personnel monitoring devices or equipment are required to be used under stated circumstances.

6. Records of monitoring inspections must be kept but few records of individual exposure are required.

7. Maximum exposure to nonemployees is not prescribed.

Let us review, then, the record of industrial safety and workmen's compensation protection against radiation injury as of 1958:

The AEC is licensing an ever increasing number of users of nuclear reactors and uses of radioisotopes by private individuals and research facilities.

The AEC has established by rule and regulation minimum standards to be adhered to by licensees to protect the health and safety of workers.

[1] The NCRP is recognized by the U.S. Department of Commerce, Bureau of Standards. It is composed of representatives of the AEC and representatives of private professional societies.

[2] Reported in an article by George T. Frampton, a member of the Illinois Atomic Power Investigation Committee. Stanford Law Review, "Radiation Exposure as Needed for a National Policy," December 1957.

The regulations issued by the AEC have not been considered mandatory by the States.

In many States no regulations have been adopted.

The regulations which have been adopted lack uniformity and fall short of the minimum standards recommended by the NCRP.

Safety inspections are inadequate, and the personnel conducting such inspections are often unskilled in the new art.

The AEC has issued no regulations as to minimum standards of workmen's compensation protection.

No State has adopted fully satisfactory provisions for medical treatment and compensation payment to workers exposed to radiation. In fact, most States have given no statutory consideration whatsoever to extending workmen's compensation to workers engaged in this new and growing enterprise.

It becomes obvious that we have failed to provide the industrial worker with protection against the hazards of radiation exposure, hazards which multiply yearly.

Adequate radiation protection does not lend itself to the multiplicity of standards and control which ensue when the States are left to regulate the field with insufficient uniform guiding criteria for several basic reasons:

1. The development of peaceful uses of nuclear energy has from its inception been recognized as a national concern. Licensing of radioisotopes is controlled by the Federal Government, as well as design and operating procedures for nuclear reactors.

2. Shortage of persons trained in the technical aspects of this new industry precludes overlapping in evaluation of techniques and promulgation of safety codes and precludes the overlapping of Federal and State inspections.

3. The standards for minimum protection and for proper medical treatment are subject to change as scientific knowledge and industrial experience broadens our understanding of radiation hazards. It would be unrealistic to expect the various jurisdictions to evaluate such advance knowledge and adopt uniform amended standards; whereas, a central agency could insure prompt expert evaluation and uniformity.

4. Effective protection requires the maintaining of permanent exposure records of workers exposed to radiation in industry. Failure of some States to keep such permanent records, or variations in standards governing the records, would render ineffective this vital control. Central records and standards would obviate the complexities caused by temporary or permanent movement of workers from State to State.

5. Centralized records of radiation exposure must be kept to keep close check upon the genetic effects of radiation upon the population of the Nation as a whole, and to insure that tolerable limits are not exceeded.

6. Unless safety standards are uniform, those States adhering to fair standards necessary for the protection of the industrial workers exposed to radiation would be placed at a severe competitive disadvantage as against those States which adopt regulations below the acceptable minimum, or as against States which adopt no minimums whatsoever. The importance of this factor

is demonstrated by the AEC estimate that construction costs of a plant designed to process highly radioactive material amount to 12 times the cost of a plant to similarly process nonradioactive material. Economic considerations may tempt marginal States and enterprises to seek standards below those requisite for safe operation.

It has been demonstrated that the Atomic Energy Acts of 1954 and 1956 have provided the AEC with jurisdiction over radiation hazards with power, through the licensing provisions of the acts, to enforce minimum standards. It has been demonstrated that the States, which have traditional jurisdiction over the industrial safety, health and workmen's compensation programs, have not adequately met the problems posed by radiation hazards.

It is for us, the workmen's compensation administrators, to assume the responsibility of devising and recommending adjustments to existing industrial safety and workmen's compensation standards and procedures. To the degree that we fail to cope with the specialized problems presented by scientific and industrial progress, we endanger the continued existence of State controlled workmen's compensation systems.

Demands have been voiced that a Federal system of workmen's compensation preempt industrial safety, medical care, and compensation adjudication and payments for workers engaged in radiation industries.

It is submitted and recommended that existing State industrial safety control and workmen's compensation facilities can and should be preserved if the existing responsibility of the AEC, as expressed in the Atomic Energy Act of 1956, is broadened and specified, as follows:

1. Licensing for construction, operation and use of nuclear reactors to remain within the jurisdiction of the AEC.

2. The AEC to issue codes with minimum requirements as to the construction, operation and use of nuclear reactors so as to insure the safety of the workers and the community in which such reactors are located.

3. Licensing for possession, handling and use of radioisotopes to remain within the jurisdiction of the AEC.

4. The AEC to issue codes containing minimum requirements for possession, handling transportation, and use of radioisotopes so as to insure the safety of industrial workers and the community in which radioisotopes may be in use or in transport.

5. The AEC to establish adequate and uniform standards for safety supervision and for qualification, tenure, and training of safety inspectors, and inspection methods and procedures.

The necessity for expert guidance and control over safety is appreciated when we consider that radiation is silent, invisible, tasteless, odorless, and cannot be felt; this hazard requires warning through mechanical, chemical, or electronic safety systems.

6. We recommend that the IAIABC adopt, with due regard to the recommendations of the AEC, uniform minimum workmen's compensation standards which will apply to workers exposed to radiation and who may develop injury due to such exposure. These minimum standards to include:

(*a*) The maintaining of individual exposure records for workers exposed to radiation in industry. Such records to

include the dates, amount of exposure, name of employer, and place of such exposure. These records to be kept at a central agency, available to the individual worker. Lifetime exposure records are imperative as the incidence of radiation on the body is cumulative, that is, repeated permissible doses may result in future disability. The cumulative effect depends upon the type of radiation, duration, intensity of exposure, and the direction of the radiation in relationship to the various organs of the body. Individuals may have varied tolerances and reactions to identical exposure. In addition, the permissible tolerance is subject to continual revision as experience and research adds to current knowledge.

Finally, as noted previously, centralized radiation exposure records must be kept to keep close check upon the genetic effects of radiation upon the population as a whole and to insure that tolerable limits are not exceeded.

(*b*) The monitoring of sources of radiation emissions on a regular basis both internally, that is, within the industrial or commercial facility, and external, that is, in the community within which such facility is situated.

(*c*) Unlimited medical care as to cost and duration. No worker suffering from injuries of radiation exposure should be deprived of the most recent and effective medical attention, whatever the cost. In addition, as the knowledge of medical treatment of radiation exposure is limited, the States should have the authority to supervise such care to the extent that there would be assurance that the best available procedures are practiced.

(*d*) The time limitation for instituting a workmen's compensation claim and notifying the employer of such intention commencing from the date that the worker knows or should have known that the injury was sustained. The average latent period for cancer due to X-ray has been estimated at 7 years and for cancer due to ionizing radiation, at 25 to 35 years. It is generally conceded that while some radiation effects occur after a short period of latency, the effects of prime importance are those which are not immediate.

(*e*) The establishment of a radiation injury claim fund in each jurisdiction made up of contributions from workmen's compensation insurance carriers licensed to do business in the State, and self-insured employers. The amount of such contributions to depend upon the best available estimates as to current claim potential and to be revised upon experience. The cost of medical treatment, temporary and permanent disability payments, and the costs of administration to be charged to the fund.

The establishment of such a fund would obviate the difficulties presented by cases involving exposures from successive employment in the same State or employment in more than one jurisdiction. The burden of the perhaps impossible task of assessing liability amongst successive employers would be avoided.

In view of the cumulative effects of radiation exposure, if the risk of workmen's compensation liability is placed solely on the last employer, employers would understandably be reluctant to hire workers who have previously had long or moderately long experience in radiation industries. Within a few years those most skilled in the technical enterprise would be barred from their usual employment and industry would suffer the loss of the best available labor.

7. It is proposed that the Federal Congress permit the AEC to issue licenses contingent upon the States adopting legislation including the minimum safety and workmen's compensation requirements outlined above; and providing that if such legislation is not in effect on or before January 1, 1960, that no new licenses be issued to individuals, corporations, research establishments, etc., situated in such jurisdictions and that prior licenses be recalled until such time as the standards are adopted.

It is submitted that the adoption of these recommendations would provide safety and workmen's compensation protection to workers engaged in radiation industries, placing each State on an equal competitive footing, and reserving to the States their traditional role of administering these programs.

The IAIABC had been invited to testify before the Joint Congressional Committee on Atomic Energy in June 1958. These hearings have been postponed to January 1959.

It is recommended that this convention authorize that the IAIABC be represented at the congressional hearings to present testimony as to the recommendations of this report.

PART IX

TITLE 10—ATOMIC ENERGY*

CHAPTER I—ATOMIC ENERGY COMMISSION

PART 20—STANDARDS FOR PROTECTION AGAINST RADIATION

In July 1955 the Commission issued for public comment a proposed regulation to establish general standards for protection of licensees, their employees, and the public against radiation hazards arising out of the possession or use of special nuclear, source, or byproduct material under license issued by AEC. In preparing the effective regulation published below, the Commission has had the benefit of numerous comments and suggestions received since publication of the proposed rules. A number of changes suggested by those comments have been incorporated in the following regulation.

The regulation establishes standards which must be followed in handling radioactive materials which are subject to the licensing authority of the Commission and provides procedures whereby deviations from such standards may be authorized on a case-to-case basis. The regulation prescribes limits which govern exposure of personnel to radiation and concentrations of radioactive material, concentrations of radioactive material which may be discharged into

* [Federal Register, Vol. 22, No. 19, Washington, Jan. 29, 1957]

air and water, and disposal of radioactive wastes. It also establishes certain precautionary procedures and administrative controls.

The standards established by this regulation will be found to agree substantially with those published by the National Committee on Radiation Protection in N.B.S. Handbook 52 "Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water," and N.B.S. Handbook 59 "Permissible Dose From External Sources of Ionizing Radiation." The National Committee on Radiation Protection has under review recommendations to limit cumulative exposures over periods of years. The Commission is giving consideration to appropriate amendments to its regulations to deal with this cumulative exposure problem.

Limitations upon levels of radiation and concentrations of radioactive material in areas affected by but not controlled by the licensee are contained principally in § 20.102 ("Permissible Levels of Radiation in Unrestricted Areas"), § 20.103 ("Concentrations in Effluents to Unrestricted Areas"), and the sections on waste disposal. The sections are designed to assure that individuals in "unrestricted areas" do not receive exposure in excess of 10 percent of the limits established for persons exposed in restricted areas. For this purpose, the sections limit levels of radiation and concentrations of radioactive material which may be created in unrestricted areas by licensees, without special authorization from the AEC, to extremely low levels. These levels are believed to be sufficiently low to assure that there is no reasonable probability of individuals in unrestricted areas receiving exposures in excess of 10 percent of the permissible levels for restricted areas. Procedures are incorporated in those sections, however, under which the Commission may authorize licensees in specific cases to create higher levels in unrestricted areas where the circumstances of the particular case are such as to provide reasonable assurance that individuals in the unrestricted areas will not receive exposures in excess of 10 percent of the limitation established for restricted areas.

It is believed that the standards incorporated in these regulations provide, in accordance with present knowledge, a very substantial margin of safety for exposed individuals. It is believed also that the standards are practical from the standpoint of licensees. It should be emphasized that the standards are subject to change with the development of new knowledge, with significant increase in the average exposure of the whole population to radiation, and with further experience in the administration of the Commission's regulatory program.

Pursuant to the Administrative Procedures Act, Public Law 404, 79th Congress, 2d Session, the following rules are published as a document subject to codification to be effective 30 days after publication in the Federal Register.

GENERAL PROVISIONS

Sec.

20.1 Purpose.
20.2 Scope.
20.3 Definitions.
20.4 Units of radiation dose.
20.5 Units of radioactivity.
20.6 Interpretations.
20.7 Communications.

PERMISSIBLE DOSES, LEVELS, AND CONCENTRATIONS

20.101 Exposure of individuals in restricted areas.
20.102 Permissible levels of radiation in unrestricted areas.
20.103 Concentrations in effluents to unrestricted areas.
20.104 Medical diagnosis, therapy, and research.
20.105 Measures to be taken after excessive exposures.

PRECAUTIONARY PROCEDURES

20.201 Surveys.
20.202 Personnel monitoring.
20.203 Caution signs, labels, and signals.
20.204 Exceptions from posting requirements.
20.205 Exemptions for radioactive materials packaged for shipment.
20.206 Instruction of personnel.
20.207 Storage of licensed material.

WASTE DISPOSAL

20.301 General requirement.
20.302 Method for obtaining approval of proposed disposal procedures.
20.303 Disposal by release into sanitary sewerage systems.
20.304 Disposal by burial in soil.

RECORDS, REPORTS, AND NOTIFICATION

20.401 Records of surveys, radiation monitoring, and disposal.
20.402 Reports of theft or loss of licensed material.

EXCEPTIONS AND ADDITIONAL REQUIREMENTS

20.501 Applications for exemptions.
20.502 Additional requirements.

ENFORCEMENT

20.601 Violations.

AUTHORITY: §§ 20.1 to 20.601 issued under sec. 161 (b), 68 Stat. 948, 42 U.S.C. 2201.

GENERAL PROVISIONS

§ 20.1 *Purpose.* (a) The regulations in this part establish standards for protection against radiation hazards arising out of activities under licenses issued by the Atomic Energy Commission and are issued pursuant to the Atomic Energy Act of 1954 (68 Stat. 919).

(b) The use of radioactive material or other sources of radiation not licensed by the Commission is not subject to the regulations in this part. However, it is the purpose of the regulations in this part to control the possession, use, and transfer of licensed material by any licensee in such a manner that exposure to such material and to radiation from such material, when added to exposures to unlicensed radioactive material and to other unlicensed sources of radiation in the possession of the licensee, and to radiation therefrom, does not exceed the standards of radiation protection prescribed in the regulations in this part.

§ 20.2 *Scope.* The regulations in this part apply to all persons who receive, possess, use or transfer byproduct material, source material, or special nuclear material under a general or specific license issued by the Commission pursuant to the regulations in Part 30, 40, or 70 of this chapter.

§ 20.3 *Definitions.* (a) As used in this part:

(1) "Act" means the Atomic Energy Act of 1954 (68 Stat. 919) including any amendments thereto;

(2) "Airborne radioactive material" means any radioactive material dispersed in the air in the form of dusts, fumes, mists, vapors, or gases;

(3) "Byproduct material" means any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material;

(4) "Commission" means the Atomic Energy Commission or its duly authorized representatives;

(5) "Government agency" means any executive department, commission, independent establishment, corporation, wholly or partly owned by the United States of America which is an instrumentality of the United States, or any board, bureau, division, service, office, officer, authority, administration, or other establishment in the executive branch of the Government;

(6) "Individual" means any human being;

(7) "Licensed material" means source material, special nuclear material, or byproduct material received, possessed, used, or transferred under a general or specific license issued by the Commission pursuant to the regulations in this chapter;

(8) "License" means a license issued under the regulations in Part 30, 40, or 70 of this chapter. "Licensee" means the holder of such license;

(9) "Person" means (i) any individual, corporation, partnership, firm, association, trust, estate, public or private institution, group, Government agency other than the Commission, any State, any foreign government or nation or any political subdivision of any such government or nation, or other entity; and (ii) any legal successor, representative, agent, or agency of the foregoing;

(10) "Radiation" means any or all of the following: alpha rays, beta rays, gamma rays, X-rays, neutrons, high-speed electrons, high-speed protons, and other atomic particles; but not sound or radio waves, or visible, infrared, or ultraviolet light;

(11) "Radioactive material" includes any such material whether or not subject to licensing control by the Commission;

(12) "Restricted area" means any area access to which is controlled by the licensee. "Restricted area" shall not include any areas used as residential quarters, although a separate room or rooms in a residential building may be set apart as a restricted area;

(13) "Source material" means any material except special nuclear material, which contains by weight one-twentieth of one percent (0.05 percent or more of (i) uranium, (ii) thorium, or (iii) any combination thereof;

(14) "Special nuclear material" means (i) plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission, pursuant to the provisions of section 51 of the act, determines to be special nuclear material, but does not include source material; or (ii) any material artificially enriched by any of the foregoing but does not include source material;

(15) "Unrestricted area" means any area entry into which is not controlled by the licensee, and any area used for residential quarters.

(b) Definitions of certain other words and phrases as used in this part are set forth in other sections, including:

(1) "Airborne radioactivity area" defined in § 20.203;

(2) "Radiation area" and "high radiation area" defined in § 20.202;

(3) "Personnel monitoring equipment" defined in § 20.202;
(4) "Survey" defined in § 20.201;
(5) Units of measurement of dose (rad, rem) defined in § 20.4;
(6) Units of measurement of radioactivity defined in § 20.5.

§ 20.4 *Units of radiation dose.* (a) "Dose," as used in this part, is the quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body. When the regulations in this part specify a dose during a period of time, the dose means the total quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body during such period of time. Several different units of dose are in current use. Definitions of units as used in this part are set forth in paragraphs (b) and (c) of this section.

(b) The rad, as used in this part, is a measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. One rad is the dose corresponding to the absorption of 100 ergs per gram of tissue. (One millirad (mrad)= 0.001 rad.)

(c) The rem, as used in the part, is a measure of the dose of any ionizing radiation to body tissue in terms of its estimated biological effect relative to a dose of one roentgen (r) of X-rays. (One millirem (mrem)=0.001 rem.) The relation of the rem to other dose units depends upon the biological effect under consideration and upon the conditions of irradiation. For the purpose of the regulations in this part, any of the following is considered to be equivalent to a dose of one rem:

(1) A dose of 1 r due to X— or gamma radiation;
(2) A dose of 1 rad due to X—, gamma, or beta radiation;
(3) A dose of 0.1 rad due to neutrons or high energy protons;
(4) A dose of 0.05 rad due to particles heavier than protons and with sufficient energy to reach the lens of the eye;

If it is more convenient to measure the neutron flux, or equivalent, than to determine the neutron dose in rads, as provided in subparagraph (3) of this paragraph, one rem of neutron radiation may, for purposes of the regulations in this part, be assumed to be equivalent to 14 million neutrons per square centimeter incident upon the body; or, if there exists sufficient information to estimate with reasonable accuracy the approximate distribution in energy of the neutrons, the incident number of neutrons per square centimeter equivalent to one rem may be estimated from the following table:

Neutron energy	Number of neutrons per square centimeter equivalent to a dose of 1 rem
Thermal	960×10^6
0.0001 mev	480×10^6
0.01 mev	480×10^6
0.1 mev	96×10^6
0.5 mev	38×10^6
1 mev	29×10^6
2 mev	19×10^6
3 mev. and higher	14×10^6

§ 20.5 *Units of radioactivity.* (a) Radioactivity is commonly, and for purposes of the regulations in this part shall be, measured in terms of disintegrations per unit time or in curies. One curie (c)$=3.7\times10^{10}$ disintegrations per second (dps)$=2.2\times10^{12}$ disintegrations per minute (dpm). A commonly used submultiple of the curie is the microcurie (μc). One μc$=0.000001$ c$=3.7\times10^{4}$ dps$=2.2\times10^{6}$ dpm.

NOTE: Many radioisotopes disintegrate into isotopes which are also radioactive. In expressing maximum permissible concentrations in air and water of these materials, as in Appendix B of this part, the activity stated is that of the parent isotope. In some cases, the fact that daughter products may contribute to the total dose has been taken into account in the determination of the maximum permissible concentration of the parent isotopes. In the tables of Appendix B of this part this is indicated by writing $Ba^{140}+La^{140}$, $Sr^{90}+Y^{90}$, $Rn^{222}+$dr, $Ra^{226}+\frac{1}{2}$ dr, etc.

EXAMPLE. In Column 1, Table I, Appendix B the maximum permissible concentration of Ba^{140} in air for occupational use is $2+10^{-7}$ac/ml. This is the maximum permissible concentration regardless of whether or not any of the La^{140} which may have resulted from the decay of the Ba^{140} is present or not. However, the value given for BA^{140} is less than it would be if La^{140} were a stable isotope, not only because of the possibility of La^{140} in the air but principally because, if the Ba^{140} is inhaled, its radioactive decay in the body will result in the production of La^{140} in the body.

(b) *Radon.* Airborne radioactivity of radon and its decay products may be determined by measurement of the activity of one or more decay products on dust filtered from the air. For purposes of the regulations in this part, the limit prescribed here will be considered to be met if the measured radioactivity of one or more decay products (for example, RaC′) does not exceed that which would result from the occurrence, at the time of sampling, of 1×10^{-7} microcuries, per milliliter of air, of Rn^{222} and each of its short-lived decay products, RaA, RaB, RaC, and RaC′. For this purpose, due allowance shall be made for changes in the radioactivity of the measured decay products from time of sampling through the period of measurement.

(c) *Natural uranium and natural thorium.* Natural uranium and natural thorium occur as mixtures of isotopes of the respective elements. In the case of uranium or of thorium, the number of microcuries shall be determined by dividing the total rate, in dpm, of alpha emissions from the mixture by 2.2×10^{6} dpm per μ c.

§ 20.6 *Interpretations.* Except as specifically authorized by the Commission in writing, no interpretation of the meaning of the regulations in this part by any officer or employee of the Commission other than a written interpretation by the General Counsel will be recognized to be binding upon the Commission.

§ 20.7 *Communications.* All communications and reports concerning the regulations in this part, and applications filed under them, should be addressed to the Atomic Energy Commission, 1901 Constitution Avenue NW., Washington 25, D.C., Attention: Division of Civilian Application.

PERMISSIBLE DOSES, LEVELS, AND CONCENTRATIONS

§ 20.101 *Exposure of individuals in restricted areas*—(a) *Exposure to radiation.* (1) Except as provided in subparagraph (2) of this paragraph, no licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual in a restricted area to receive in any period of seven consecutive days from radioactive mate-

rial and other sources of radiation in the licensee's possession a dose in excess of the limits specified in Appendix A of this part.

(2) A licensee may permit an individual in a restricted area to receive a dose in excess of the limits established in subparagraph (1) of this paragraph: *Provided*, (i) That the dose during any period of 7 consecutive days does not exceed three times the limits specified in Appendix A of this part, and (ii) that the dose during any period of 13 consecutive weeks does not exceed 10 times the limits specified in Appendix A of this part.

(b) No licensee shall possess, use or transfer licensed material in such a manner as to cause any individual in a restricted area to be exposed to airborne radioactive material possessed by the licensee in an average concentration in excess of the limits specified in Appendix B, Table I, of this part.

The limits given in Appendix B, Table I of this part, are based upon exposure to the concentrations specified for forty hours in any period of seven consecutive days. In any such period where the number of hours of exposure is less than forty, the limits specified in the table may be increased proportionately. In any such period, where the number of hours of exposure is greater than forty, the limits specified in the table shall be decreased proportionately.

(c) *Exposure of minors.* No licensee shall possess, use, or transfer licensed material in such a manner as to cause any individual under 18 years of age within a restricted area to receive in any period of seven consecutive days from radioactive material and other sources of radiation in the licensee's possession a dose in excess of 10 percent of the limits specified in Appendix A of this part, or to be exposed to airborne radioactive material possessed by the licensee in a concentration in excess of the limits specified in Appendix B, Table II, of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than a week.

§ 20.102 *Permissible levels of radiation in unrestricted areas.* (a) There may be included in any application for a license or for amendment of a license proposed limits upon levels of radiation in unrestricted areas resulting from the applicant's possession or use of radioactive material and other sources of radiation. Such applications should include information as to anticipated average radiation levels and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrates that the proposed limits are not likely to cause any individual to receive a dose in any period of seven consecutive days in excess of 10 percent of the limits specified in Appendix A of this part.

(b) Except as authorized by the Commission pursuant to paragraph (a) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to create in any unrestricted area from radioactive material and other sources of radiation in his possession:

(1) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of two millirems in any one hour, or

(2) Radiation levels which, if an individual were continuously present in the area, could result in his receiving a dose in excess of 100 millirems in any seven consecutive days.

20.103 *Concentrations in effluents to unrestricted areas.* (a) There may be included in any application for a license or for amendment of a license proposed limits upon concentrations of licensed and other radioactive material released into air or water in unrestricted areas as a result of the applicant's proposed activities. Such applications should include information as to anticipated average concentrations and anticipated occupancy times for each unrestricted area involved. The Commission will approve the proposed limits if the applicant demonstrates that it is not likely that any individual will be exposed to concentrations in excess of the limits specified in Appendix B, Table II, of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than one year.

(b) Except as authorized by the Commission pursuant to § 20.302 or paragraph (a) of this section, no licensee shall possess, use, or transfer licensed material in such a manner as to release into air or water in any unrestricted area any concentration of radioactive material in excess of the limits specified in Appendix B, Table II of this part. For purposes of this paragraph, concentrations may be averaged over periods not greater than one year.

(c) For purposes of this section, determinations as to the concentration of radioactive material shall be made with respect to the point where such material leaves the restricted area. Where the radioactive material leaves the restricted area in a stack, tube, pipe, or similar conduit, the determination may be made with respect to the point where the material leaves such conduit.

(d) The provisions of this section do not apply to disposal of radioactive material into sanitary sewerage systems (see § 20.303).

§ 20.104 *Medical diagnosis, therapy, and research.* Nothing in the regulations in this part shall be interpreted as limiting the intentional exposure of patients to radiation for the purpose of medical diagnosis or medical therapy.

§ 20.105 *Measures to be taken after excessive exposures.* In the event that any individual in a restricted area receives a dose or is exposed to concentrations of radioactive material in excess of the permissible limits established in § 20.101, the licensee shall limit the weekly dose or exposure of the individual to 10 percent of such permissible limit until such time as the average weekly dose or exposure to the individual for the period beginning with the week in which the excessive dose or exposure occurred is less than the permissible limit established in § 20.101.

PRECAUTIONARY PROCEDURES

§ 20.201 *Surveys.* (a) As used in the regulations in this part, "survey" means an evaluation of the radiation hazards incident to the production, use, release, disposal, or presence of radioactive materials or other sources of radiation under a specific set of conditions. When appropriate, such evaluation includes a physical survey of the location of materials and equipment, and measurements of levels of radiation or concentrations of radioactive material present.

(b) Each licensee shall make or cause to be made such surveys as may be necessary for him to comply with the regulations in this part.

§ 20.202 *Personnel monitoring.* (a) Each licensee shall supply appropriate personnel monitoring equipment to, and shall require the use of such equipment by:

(1) Each individual who enters a restricted area under such circumstances that he receives, or is likely to receive, a dose in excess of 25 percent of the limits specified in Appendix A of this part;

(2) Each individual who enters a high radiation area.

(b) As used in this part,

(1) "Personnel monitoring equipment means devices designed to be worn or carried by an individual for the purpose of measuring the dose received (e.g., film badges, pocket chambers, pocket dosimeters, film rings, etc.);

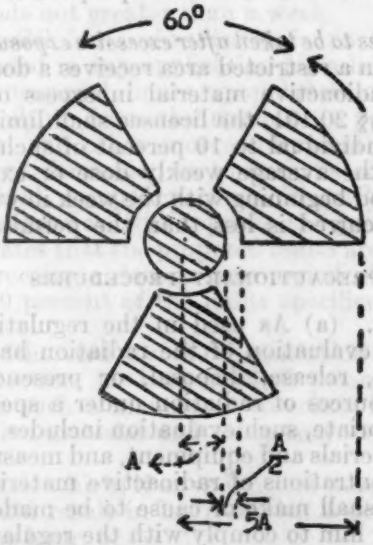
(2) "Radiation area" means any area, accessible to personnel, in which there exists radiation, originating in whole or in part within licensed material, at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 millirem, or in any 5 consecutive days a dose in excess of 150 millirem;

(3) "High radiation area" means any area, accessible to personnel, in which there exists radiation originating in whole or in part within licensed material at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 millirem.

§ 20.203 *Caution signs, labels, and signals.* (a) (1) Except as otherwise authorized by the Commission, symbols prescribed by this section shall use the conventional radiation caution colors (magenta or purple on yellow background). The symbol prescribed by this section is the conventional three-bladed design:

RADIATION SYMBOL

1. Cross-hatched area is to be magenta or purple.
2. Background is to be yellow.



(2) In addition to the contents of signs and labels prescribed in this section, licensees may provide on or near such signs and labels any additional information which may be appropriate in aiding individuals to minimize exposure to radiation or to radioactive material.

(b) *Radiation areas.* Each radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [1]

RADIATION AREA

(c) *High radiation areas.* (1) Each high radiation area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [1]

HIGH RADIATION AREA

(2) Each high radiation area shall be equipped with a control device which shall either cause the level of radiation to be reduced below that at which an individual might receive a dose of 100 millirem in one hour upon entry into the area or shall energize a conspicuous visible or audible alarm signal in such a manner that the individual entering and the licensee or a supervisor of the activity are made aware of the entry. In the case of a high radiation area established for a period of 30 days or less, such control device is not required.

(d) *Airborne radioactivity areas.* (1) As used in the regulations in this part, "airborne radioactivity area" means (i) any room, enclosure, or operating area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations in excess of the amounts specified in Appendix B, Table I, Column 1 of this part; or (ii) any room, enclosure, or operating area in which airborne radioactive material composed wholly or partly of licensed material exists in concentrations which, averaged over the number of hours in any week during which individuals are in the area, exceed 25 percent of the amounts specified in Appendix B, Table I, Column 1 of this part.

(2) Each airborne radioactivity area shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [1]

AIRBORNE RADIOACTIVITY AREA

(e) *Additional requirements.* (1) Each area or room in which licensed material is used or stored and which contains any radioactive material (other than natural uranium or thorium) in an amount exceeding 10 times the quantity of such material specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

CAUTION [1]

RADIOACTIVE MATERIAL(S)

(2) Each area or room in which natural uranium or thorium is used or stored in an amount exceeding one-hundred times the quantity specified in Appendix C of this part shall be conspicuously posted with a sign or signs bearing the radiation caution symbol and the words:

[1] Or "Danger".

CAUTION [1]

RADIOACTIVE MATERIAL(S)

(f) *Containers.* (1) Each container in which is transported, stored, or used a quantity of any licensed material (other than natural uranium or thorium) greater than the quantity of such material specified in Appendix C of this part shall bear a durable, clearly visible label bearing the radiation caution symbol and the words:

CAUTION [1]

RADIOACTIVE MATERIAL

(2) Each container in which natural uranium or thorium is transported, stored, or used in a quantity greater than ten times the quantity specified in Appendix C of this part shall bear a durable, clearly visible label bearing the radiation caution symbol and the words:

CAUTION [1]

RADIOACTIVE MATERIAL

(3) Notwithstanding the provisions of subparagraphs (1) and (2) a label shall not be required:

(i) If the concentration of the material in the container does not exceed that specified in Appendix B, Table I, Column 2 of this part, or

(ii) For laboratory containers, such as beakers, flasks and test tubes, used transiently in laboratory procedures, when the user is present.

(4) Where containers are used for storage, the labels required in this paragraph shall state also the quantities and kinds of radioactive materials in the containers and the date of measurement of the quantities.

§ 20.204 *Exceptions from posting requirements.* Notwithstanding the provisions of § 20.203,

(a) A room or area is not required to be posted with a caution sign because of the presence of a sealed source provided the radiation level twelve inches from the surface of the source container or housing does not exceed five millirem per hour.

(b) Rooms or other areas in hospitals are not required to be posted with caution signs because of the presence of patients containing byproduct material provided that there are personnel in attendance who shall take the precautions necessary to prevent the exposure of any individual to radiation or radioactive material in excess of the limits established in the regulations in this part.

(c) Caution signs are not required to be posted at areas or rooms containing radioactive materials for periods of less than eight hours provided that (1) the materials are constantly attended during such periods by an individual who shall take the precautions necessary to prevent the exposure of any individual to radiation or radioactive materials in excess of the limits established in the regulations in this part and; (2) such area or room is subject to the licensee's control.

[1] Or "Danger".

§ 20.205 *Exemptions for radioactive materials packaged for shipment.* Radioactive materials packaged and labeled in accordance with regulations of the Interstate Commerce Commission shall be exempt from the labeling and posting requirements of § 20.203 during shipment, provided that the inside containers are labeled in accordance with the provisions of § 20.203(f).

§ 20.206 *Instruction of personnel.* All individuals working in or frequenting any portion of a restricted area shall be informed of the occurrence of radioactive materials or of radiation in such portion, and shall be instructed in the hazards of excessive exposure to such materials or radiation and in precautions or procedures to minimize exposure.

§ 20.207 *Storage of licensed material.* Licensed materials stored in an unrestricted area shall be secured against unauthorized removal from the place of storage.

WASTE DISPOSAL

§ 20.301 *General requirement.* No licensee shall dispose of licensed material except:

(1) By transfer to an authorized recipient as provided in the regulations in Part 30, 40, or 70 of this chapter, whichever may be applicable; or

(2) As authorized pursuant to § 20.302; or

(3) As provided in § 20.303 or § 20.304, applicable respectively to the disposal of licensed material by release into sanitary sewerage systems or burial in soil, or in § 20.103 (Concentrations in Effluents to Unrestricted Areas).

§ 20.302 *Method for obtaining approval of proposed disposal procedures.* Any licensee or applicant for a license may apply to the Commission for approval of proposed procedures to dispose of licensed material in a manner not otherwise authorized in the regulations in this chapter. Each application should include a description of the licensed material and any other radioactive material involved, including the quantities and kinds of such material and the levels of radioactivity involved, and the proposed manner and conditions of disposal. The application should also include an analysis and evaluation of pertinent information as to the nature of the environment, including topographical, geological, meteorological, and hydrological characteristics; usage of ground and surface waters in the general area; the nature and location of other potentially affected facilities; and procedures to be observed to minimize the risk of unexpected or hazardous exposures.

§ 20.303 *Disposal by release into sanitary sewerage systems.* No licensee shall discharge licensed material into a sanitary sewerage system unless:

(a) It is readily soluble or dispersible in water; and

(b) The quantity of any licensed or other radioactive material released into the system by the licensee in any one day does not exceed the larger of subparagraphs (1) or (2) of this paragraph:

(1) The quantity which, if diluted by the average daily quantity of sewage released into the sewer by the licensee, will result in an average concentration equal to the limits specified in Appendix B, Table I, Column 2 of this part; or

(2) Ten times the quantity of such material specified in Appendix C of this part; and

(c) The quantity of any licensed or other radioactive material released in any one month, if diluted by the average monthly quantity of water released by the licensee, will not result in an average concentration exceeding the limits specified in Appendix B, Table I, Column 2 of this part; and

(d) The gross quantity of licensed and other radioactive material released into the sewerage system by the licensee does not exceed one curie per year.

Excreta from individuals undergoing medical diagnosis or therapy with radioactive material shall be exempt from any limitations contained in this section.

§ 20.304 *Disposal by burial in soil.* No licensee shall dispose of licensed material by burial in soil unless:

(a) The total quantity of licensed and other radioactive materials buried at any one location and time does not exceed, at the time of burial, 1,000 times the amount specified in Appendix C of this part; and

(b) Burial is at a minimum depth of four feet; and

(c) Successive burials are separated by distances of at least six feet and not more than 12 burials are made in any year.

RECORDS, REPORTS, AND NOTIFICATION

§ 20.401 *Records of surveys, radiation monitoring, and disposal.* (a) Each licensee shall maintain records showing the radiation exposures of all individuals subject to personnel monitoring control under § 20.202 of the regulations in this part.

(b) Each licensee shall maintain records showing the name of each individual exposed to radiation pursuant to § 20.101(a)(2) and the weekly dose of each such individual for the 13 consecutive weeks of highest cumulative weekly dose.

(c) Each licensee shall maintain records in the same units used in the appendices to this part, showing the results of surveys required by § 20.201(b), and disposals made under §§ 20.302, 20.303, and 20.304.

§ 20.402 *Reports of theft or loss of licensed material.* Each licensee shall report promptly to the Commission after its occurrence becomes known to the licensee any loss or theft of licensed material in such quantities and under such circumstances that it appears to the licensee that a substantial hazard may result to persons in unrestricted areas.

EXCEPTIONS AND ADDITIONAL REQUIREMENTS

§ 20.501 *Applications for exemptions.* The Commission may, upon application by any licensee or upon its own initiative, grant such exemptions from the requirements of the regulations in this part as it determines are authorized by law and will not result in undue hazard to life or property.

§ 20.502 *Additional requirements.* The Commission may, by rule, regulation, or order, impose upon any licensee such requirements, in addition to those established in the regulations in this part, as it deems appropriate or necessary to protect health or to minimize danger to life or property.

ENFORCEMENT

§ 20.601 *Violations.* An injunction or other court order may be obtained prohibiting any violation of any provision of the act or any regulation or order issued thereunder. Any person who willfully violates any provision of the act or any regulation or order issued thereunder may be guilty of a crime and, upon conviction, may be punished by fine or imprisonment or both, as provided by law.

APPENDIX A

Permissible weekly dose

Conditions of exposure		Dose in critical organs (mrem)			
Parts of body	Radiation	Skin, at basal layer of epidermis	Blood forming organs	Gonads	Lens of eye
Whole body	Any radiation with half-value-layer greater than 1 mm of soft tissue.	[1] 600	[1] 300	[1] 300	[1] 300
Whole body	Any radiation with half-value-layer less than 1 mm of soft tissue.	1,500	300	300	300
Hands and forearms or feet and ankles or head and neck.	Any radiation	[2] 1,500			

[1] For exposures of the whole body to X or gamma rays up to 3 mev, this condition may be assumed to be met if the "air dose" does not exceed 300 mr, provided the dose to the gonads does not exceed 300 mrem. "Air dose" means that the dose is measured by an appropriate instrument in air in the region of highest dosage rate to be occupied by an individual, without the presence of the human body or other absorbing and scattering material.

[2] Exposure of these limited portions of the body under these conditions does not alter the total weekly dose of 300 mrem permitted to the bloodforming organs in the main portion of the body, to the gonads, or to the lens of the eye.

APPENDIX B

Permissible concentrations in air and water above natural background

Materia	Table I		Table II	
	Column 1 [1] Air (2)	Column 2 [2] Water (3)	Column 1 [1] Air (2)	Column 2 [2] Water (3)
A^{41}	1.6×10^{-6}	1.4×10^{-3}	5×10^{-6}	5×10^{-4}
Ag^{105}	3.6×10^{-5}	5	1.2×10^{-6}	1.6×10^{-1}
Ag^{111}	1×10^{-4}	13	3×10^{-6}	4×10^{-1}
Am^{241}	8×10^{-11}	4×10^{-4}	3×10^{-13}	1.3×10^{-6}
As^{76}	7×10^{-6}	6×10^{-1}	2×10^{-7}	2×10^{-3}
At^{211}	9×10^{-10}	6×10^{-6}	3×10^{-11}	2×10^{-7}
Au^{198}	3.4×10^{-7}	9×10^{-6}	1.1×10^{-6}	3×10^{-4}
Au^{199}	8×10^{-7}	2×10^{-5}	2.5×10^{-6}	7×10^{-4}
$Ba^{140}+La^{140}$	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
Be^{7}	1.3×10^{-5}	3	4×10^{-7}	1×10^{-1}
C^{14}	1.4×10^{-6}	1×10^{-2}	5×10^{-8}	3.6×10^{-4}
Ca^{45}	9×10^{-8}	1.3×10^{-6}	3×10^{-9}	5×10^{-6}
$Cd^{109}+Ag^{109}$	2×10^{-7}	2×10^{-4}	7×10^{-6}	7×10^{-4}
$Ce^{144}+Pr^{144}$	2×10^{-6}	1×10^{-1}	7×10^{-10}	2.6×10^{-6}
Cl^{36}	1×10^{-6}	7×10^{-3}	4×10^{-8}	2.4×10^{-4}
Cm^{242}	5×10^{-10}	2.7×10^{-3}	1.8×10^{-11}	1×10^{-4}
Co^{60}	3.4×10^{-6}	5×10^{-2}	1.2×10^{-7}	1.8×10^{-3}
Cr^{51}	2.4×10^{-5}	1.4	8×10^{-7}	5×10^{-3}
$Cs^{137}+Ba^{137}$	6×10^{-7}	4.5×10^{-3}	2×10^{-8}	1.5×10^{-4}
Cu^{64}	2×10^{-5}	2.5×10^{-1}	6×10^{-7}	8×10^{-3}
Eu^{154}	2×10^{-6}	1×10^{-1}	6×10^{-10}	3×10^{-3}
F^{18}	3.5×10^{-4}	2.6	1.2×10^{-5}	9×10^{-2}
Fe^{55}	1.8×10^{-5}	1.3×10^{-2}	6×10^{-8}	4×10^{-4}
Fe^{59}	5×10^{-6}	3.3×10^{-4}	1.5×10^{-9}	1.1×10^{-6}
Ga^{72}	1×10^{-5}	26	3.4×10^{-7}	9×10^{-2}
Ge^{71}	1×10^{-4}	27	3.6×10^{-6}	9×10^{-2}

See footnotes at end of table, p. 252.

APPENDIX B—Continued

Permissable concentrations in air and water above natural background—Continued

Material	Table I		Table II	
	Column 1 [1] Air (2)	Column 2 [2] Water (3)	Column 1 [1] Air (2)	Column 2 [2] Water (3)
H^3 (HTO or T_2O)	7×10^{-6}	5×10^{-1}	2.5×10^{-6}	1.6×10^{-2}
Ho^{166}	1×10^{-6}	70	3×10^{-7}	2.3
I^{131}	9×10^{-9}	9×10^{-4}	3×10^{-10}	3×10^{-6}
Ir^{190}	2.2×10^{-6}	4×10^{-2}	7×10^{-8}	1.3×10^{-3}
Ir^{192}	1.5×10^{-7}	2.7×10^{-3}	5×10^{-9}	9×10^{-5}
K^{42}	6×10^{-6}	4×10^{-2}	2×10^{-7}	1.4×10^{-3}
La^{140}	4×10^{-6}	3.4	1.4×10^{-7}	1.1×10^{-1}
Lu^{177}	1.5×10^{-5}	70	5×10^{-7}	2.4
Mn^{56}	8×10^{-6}	5×10^{-1}	3×10^{-7}	1.5×10^{-2}
Mo^{99}	5×10^{-5}	40	1.8×10^{-4}	1.4
Na^{24}	5×10^{-6}	2.4×10^{-2}	1.6×10^{-7}	8×10^{-4}
Nb^{95}	1.3×10^{-6}	1.2×10^{-2}	4×10^{-8}	4×10^{-4}
Ni^{59}	5×10^{-5}	7×10^{-1}	1.6×10^{-6}	2.5×10^{-2}
P^{32}	4×10^{-7}	6×10^{-4}	1.4×10^{-8}	2×10^{-5}
Pb^{210}	2×10^{-8}	4×10^{-2}	6×10^{-7}	1.4×10^{-2}
$Pb^{203}+Rh^{103}$	2×10^{-6}	3×10^{-2}	7×10^{-8}	1×10^{-5}
Pm^{147}	6×10^{-7}	3	2×10^{-8}	1×10^{-1}
Po^{210} (soluble)	6×10^{-10}	9×10^{-4}	2×10^{-11}	3×10^{-4}
Po^{210} (insoluble)	2×10^{-10}		7×10^{-12}	
Pr^{143}	2.8×10^{-6}	1	7×10^{-8}	3.6×10^{-2}
Pu^{239} (soluble)	6×10^{-12}	4.5×10^{-6}	2×10^{-13}	1.5×10^{-7}
Pu^{239} (Insoluble)	6×10^{-12}		2×10^{-13}	
Ra^{226}+1/2 dr	2.4×10^{-11}	1.2×10^{-7}	8×10^{-13}	4×10^{-3}
Rb^{86}	1.1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
Re^{189}	2.4×10^{-6}	2.4×10^{-1}	8×10^{-7}	8×10^{-3}
Rh^{105}	3×10^{-6}	5×10^{-2}	1×10^{-7}	1.6×10^{-3}
Rh^{223}+dr	1×10^{-7}	6×10^{-6}	3.3×10^{-9}	2×10^{-7}
$Ru^{106}+Rh^{106}$	8×10^{-9}	4×10^{-1}	2.6×10^{-9}	1.3×10^{-3}
S^{35}	3×10^{-6}	1.5×10^{-3}	1×10^{-7}	5×10^{-5}
Sc^{46}	2×10^{-7}	1	7×10^{-9}	3.6×10^{-2}
Sm^{151}	4×10^{-6}	6×10^{-1}	1.3×10^{-8}	2×10^{-2}
Sn^{113}	1.7×10^{-6}	5×10^{-1}	6×10^{-8}	1.6×10^{-2}
Sr^{89}	6×10^{-8}	2×10^{-4}	2×10^{-9}	7×10^{-6}
$Sr^{90}+Y^{90}$	6×10^{-10}	2.4×10^{-6}	2×10^{-11}	8×10^{-5}
Te^{96}	8×10^{-6}	8×10^{-2}	3×10^{-7}	3×10^{-3}
Te^{127}	3×10^{-7}	8×10^{-2}	1×10^{-8}	3×10^{-3}
Te^{129}	1.2×10^{-7}	3.3×10^{-3}	4×10^{-9}	1.1×10^{-3}
Th^{234}	2×10^{-6}	10	6×10^{-8}	3×10^{-1}
Th-natural (soluble)	5×10^{-11}	1.5×10^{-6}	1.7×10^{-12}	5×10^{-5}
Th-natural (insoluble)	5×10^{-11}		1.7×10^{-12}	
Tm^{170}	1.5×10^{-7}	8×10^{-1}	5×10^{-9}	2.5×10^{-2}
U-natural (soluble)[3]	5×10^{-11}	2×10^{-4}	1.7×10^{-12}	7×10^{-6}
U-natural (insoluble)[3]	5×10^{-11}		1.7×10^{-12}	
U^{233} (soluble)	4×10^{-10}	4.5×10^{-4}	1×10^{-11}	1.5×10^{-5}
U^{233} (insoluble)	5×10^{-11}		1.6×10^{-12}	
V^{48}	3×10^{-6}	1.5	1×10^{-7}	5×10^{-2}
Xe^{133}	1.3×10^{-5}	1.3×10^{-2}	4×10^{-7}	4×10^{-4}
Xe^{135}	5×10^{-6}	4×10^{-3}	1.7×10^{-7}	1.4×10^{-4}
Y^{91}	1.2×10^{-7}	6×10^{-1}	4×10^{-9}	2×10^{-2}
Zn^{65}	6×10^{-6}	2×10^{-1}	2×10^{-7}	6×10^{-3}
Unidentified beta or gamma emitters or any undetermined mixtures of beta or gamma emitters			1×10^{-9}	1×10^{-7}
Unidentified alpha emitters or any undetermined mixtures of alpha emitters			5×10^{-13}	1×10^{-7}

[1] Air concentrations are given in microcuries per milliliter of air.

[2] Water concentrations are given in microcuries per milliliter of water. These figures also apply to foodstuffs in microcuries per gram (wet-weight).

[3] For enriched uranium the same radioactivities per unit volume as those for natural uranium are applicable. It should be noted that the contribution of U-234 to the gross activity of enriched uranium is 20-40 times that of the U-235.

APPENDIX C

Material	Microcuries	Material	Microcuries
Ag^{105}	1	$Pd^{109}+Rh^{109}$	50
Ag^{111}	10	Pd^{109}	10
As^{76}, As^{77}	10	Pm^{147}	10
Au^{198}	10	Po^{210}	0.1
Au^{199}	10	Pr^{143}	10
$Ba^{140}+La^{140}$	1	Pu^{239}	1
Be^{7}	50	Ra^{226}	0.1
C^{14}	50	Rb^{86}	10
Ca^{45}	10	Re^{186}	10
$Cd^{109}+Ag^{109}$	10	Rh^{105}	10
$Ce^{144}+Pr^{144}$	1	$Ru^{106}+Rh^{106}$	1
Cl^{36}	1	S^{35}	50
Co^{60}	1	Sb^{124}	1
Cr^{51}	50	Sc^{46}	1
$Cs^{137}+Ba^{137}$	1	Sm^{153}	10
Cu^{64}	50	Sn^{113}	10
Eu^{154}	1	Sr^{89}	1
F^{18}	50	$Sr^{90}+Y^{90}$	0.1
Fe^{55}	50	Ta^{182}	10
Fe^{59}	1	Tc^{96}	1
Ga^{72}	10	Tc^{96}	1
Ge^{71}	50	Te^{127}	10
H^{3}(HTO or H_2O)	250	Te^{129}	1
I^{131}	10	Th (natural)	50
In^{114}	1	Tl^{204}	50
Ir^{192}	10	Tritium. See H^3	250
K^{42}	10	U (natural)	50
La^{140}	10	U^{233}	1
Mn^{52}	1	U^{234}—U^{238}	50
Mn^{56}	50	V^{48}	1
Mo^{99}	10	W^{185}	10
Na^{22}	10	Y^{90}	1
Na^{24}	10	Y^{91}	1
Nb^{95}	10	Zn^{65}	10
Ni^{59}	1	Unidentified radioactive materials or any of the above in unknown mixtures.	0.1
Ni^{63}	1		
P^{32}	10		

NOTE: The record keeping and reporting requirements contained herein have been approved by the Bureau of the Budget in accordance with the Federal Reports Act of 1942.

NOTE: For purposes of §§ 20.203 and 20.304, where there is involved a combination of isotopes in known amounts the limit for the combination should be derived as follows: Determine, for each isotope in the combination, the ratio between the quantity present in the combination and the limit otherwise established for the specific isotope when not in combination. The sum of such ratios for all the isotopes in the combination may not exceed "1" (i. e., "unity").

EXAMPLE: For purposes of § 20.304, if a particular batch contains 2,000 μc of Au^{198} and 25,000 μc of C^{14}, it may also include not more than 3,000 μc of I^{131}. This limited was determined as follows:

$$\frac{2{,}000\ \mu c\ Au^{198}}{10{,}000\ \mu c}+\frac{25{,}000\ \mu c\ C^{14}}{50{,}000\ \mu c}+\frac{3{,}000\ \mu c\ I^{131}}{10{,}000\ \mu c}=1$$

The denominator in each of the above ratios was obtained by multiplying the figure in the table by 1000 as provided in § 20.304.

[F. R. Doc. 57-511; Filed, Jan. 25, 1957; 12:30 p. m.]

Dated at Washington, D.C., this 16th day of January 1957.

For the Atomic Energy Commission.

K. E. FIELDS,
General Manager.

PART X

A SUMMARY OF ACCIDENTS AND INCIDENTS INVOLVING RADIATION IN ATOMIC ENERGY ACTIVITIES, PREPARED BY THE ATOMIC ENERGY COMMISSION

JUNE 1945 THROUGH DECEMBER 1955

This report has been reproduced directly from the best available copy.

PREFACE

The motto on the Archives Building in Washington—"Study the Past—What Is Past Is Prologue"—should be equally applicable to the accidents which have occurred in the atomic energy program. This paper is written to set down the past so that full benefit may be obtained from the experience gained as a result of accidents which have occurred.

There are three broad classifications of accidents in the atomic energy program. In the first group, and by far the most numerous, are those in no way related to atomic energy. Falls, electrocutions, motor vehicle accidents, and construction equipment accidents comprise the majority of accidents in this classification.

The second classification includes those accidents which are somewhat peculiar to the atomic energy industry in that the materials or the processes are closely related to the program and possibly not in widespread use outside the industry.[1]

The third classification includes those accidents in which radiation is the prime or at least a major factor. *This report will deal with this classification.*

Before reading the text and drawing any conclusions, the reader must thoroughly understand the basic difference between the radiation safety program which started with the Manhattan Engineer District, and which has been carried forward by the Atomic Energy Commission, and all other safety programs as we know them.

In industry generally, safety regulations have grown out of a number of serious accidents related to a particular cause. Finally, public opinion has reacted and a safety program has been designed to reduce the number of accidents from this specific cause.

Prior to the commencement of work on the atomic bomb, radiation accidents and injuries in industry were relatively few. These cases were sufficiently serious, however, to point out the necessity for a stringent radiation safety program right from the start. Human nature being what it is, many people consider a period of trial and error to be a necessary evil in the control of traumatic injury. Because of the long-range possibilities of radiation injury, however, the trial-and-error method was not at all acceptable. From the beginning, the policy was "to maintain strict control over the manner and methods of work * * * which should result in the prevention of all the conditions associated with delayed injurious effects."[2]

[1] In the section "Fires" there are a number of instances which fall partially in the second and third categories. No attempt has been made, therefore, to record every fire here, but a representative sampling has been included.

[2] "Industrial Medicine on the Plutonium Project," edited by Robert S. Stone, McGraw-Hill Book Co., Inc., 1951.

For this reason, the report cannot be considered in the same light as would be a report, for instance, of all of the explosions which took place as steam boilers were developed to their present level. Consideration must be given to the hundreds of hazard evaluation studies which were made in one form or another and which provided vicariously the knowledge which, in earlier times, was gained at the cost of human suffering and property damage.

It must be realized, therefore, that the comparatively few incidents here cited form the total of the unfavorable incidents [3] *over a period of 11 years in this field, in which upwards of 300,000 people were engaged at the peak.*

The principal lesson to be drawn is that, if the record of safe operation is to be maintained, we cannot slip back into old-fashioned methods of hazard evaluation by bitter experience only.

The effect of hazard evaluation on the overall safety program is evidenced by the fatality record which is a good single index of safety performance on a project of this size. During the years 1943–55, the atomic energy program suffered 184 fatalities. This is exactly half the number of fatalities that would have occurred had the atomic energy program incurred fatal accidents at the rate reported by the National Safety Council industrial members (who generally have records superior to those of industry as a whole). Of the 184 fatalities, only 2 were attributable to radiation; the balance to typical industrial accident causes: falls (43), electrocutions (31), mobile equipment, e.g., cranes and bulldozers (25), motor vehicle (20), miscellaneous (63).

It is therefore apparent that hazard evaluation and preplanning will provide safe working conditions not only in the field of nuclear energy but in all industry. Experience has taught us that it is not necessary to have accidents to learn how to prevent accidents.

The recommendations for corrective action in the reports, which were written shortly after the incident occurred, are not necessarily to be construed as general in application since they are often only appropriate locally or at the time.

D. F. Hayes.

CRITICALITY INCIDENTS

FATALITY FROM CRITICAL MASS EXPERIMENT [1945]

Los Alamos, N. Mex., August 8, 1945:

Nature of incident

Inadvertent supercritical assembly of fissionable material.

Description of operation

In the process of making critical mass studies and measurements, an employee was stacking blocks of tamper material around a mass of fissionable material.

Details of incident

Employee was working in the laboratory at night alone except for a guard seated 12 feet away.

As the assembly neared a critical configuration, employee was lifting one last piece of tamper material which was quite heavy. As

[3] A few incidents which occurred outside AEC-sponsored activities are included because of their happening in the field of nuclear research. The pertinent Canadian NRX reactor failure is not included. A report on this incident was published in "Mechanical Engineering," February 1955, p. 124.

this piece neared the setup, the instrument indicated that fission multiplication would be produced, and as the employee moved his hand to set the block at a distance from the pile he dropped the block which landed directly on top of the setup.

A "blue-glow" was observed and the employee proceeded to disassemble the critical material and its tamper. In doing so, he added heavily to the radiation dosage to his hands and arms.

Nature of injuries or loss

Employee who performed the experiment received radiation dosage sufficient to result in injuries from which he died 24 days later.

The guard was exposed beyond the established daily limit, but suffered no observable permanent injury.[4]

Remarks

As a result of this incident, a special committee was set up to review the work carried on whenever fissionable material was being assembled under conditions where the assembly might conceivably become critical, and to make appropriate safety recommendations. The regulations given below resulted from the work of this committee and these aimed not only at reducing the possibility of a similar incident but also at moderating the severity should an untoward incident occur:

1. Two special lists were prepared naming the persons who were the only ones permitted to do this work; one list carried the names of persons who would head up such work.
2. A minimum of two persons was required to be present in addition to guard personnel. The maximum number of people permitted was also controlled.
3. Before starting, the experiment must be planned including mode of operation and behavior in all contingencies.
4. At least two monitoring instruments must be operating, each giving a clearly audible indication of the neutron intensity at all times during the experiment.
5. Any changes in an assembly involving fissionable material must be made by one person at a time, slowly and readily reversible.
6. There shall never be two assemblies, which might become critical, in the same building at the same time.
7. All operators associated with the experiment must be in agreement about the safety of procedures all through the operation. If any disagreement arises, operations must be stopped until agreement has been reached.

Substantial consideration was given to the development of mechanical remote control devices as a long-range program, although there was not universal agreement whether or not this should be done. In the ensuing months some design and fabrication work was carried on. After 1946, all similar work was carried out with remote control systems without exposure to personnel.

FATALITY FROM CRITICAL MASS EXPERIMENT (1946)

Nature of incident

Inadvertent supercritical assembly of fissionable material.

[4] "The Annals of Internal Medicine," vol. 36, pt. I, February 1952, published by the American College of Physicians, describes the medical aspects of this incident (cases 1 and 2).

Description of operation

A senior scientist was demonstrating technique of critical assembly and associated studies and measurements to another scientist. The particular technique employed in the demonstration was to bring a hollow hemisphere of beryllium around a mass of fissionable material which was resting in a similar lower hollow hemisphere.

Details of incident

The system was checked with two one-inch spacers between the upper hemisphere and the lower shell which contained the fissionable material; the system was subcritical at this time.

Then the spacers were removed so that one edge of the upper hemisphere rested on the lower shell while the other edge of the upper hemisphere was supported by a screw driver. This latter edge was slowly permitted to approach the lower shell. While one hand held the screw driver, the other hand was holding the upper shell with the thumb placed in an opening at the polar point.

At this time, the screw driver apparently slipped and the upper shell fell into position around the fissionable material.

There were eight people present in the room where this demonstration was being carried out. Of these, two were directly engaged in the work leading to this incident.

The "blue-glow" was observed, a heat wave felt, and immediately the top shell was slipped off and everyone left the room.

Nature of injuries or loss

Scientist (A) who was demonstrating the experiment received radiation dosage sufficient to result in injuries from which he died 9 days later. The scientist (B) working with the deceased received radiation dosage sufficient to cause serious injuries and some permanent partial disability.

The other six employees in the room (C, D, E, F, G, H) were exposed beyond the established daily limit, but suffered no observable permanent injury.[5]

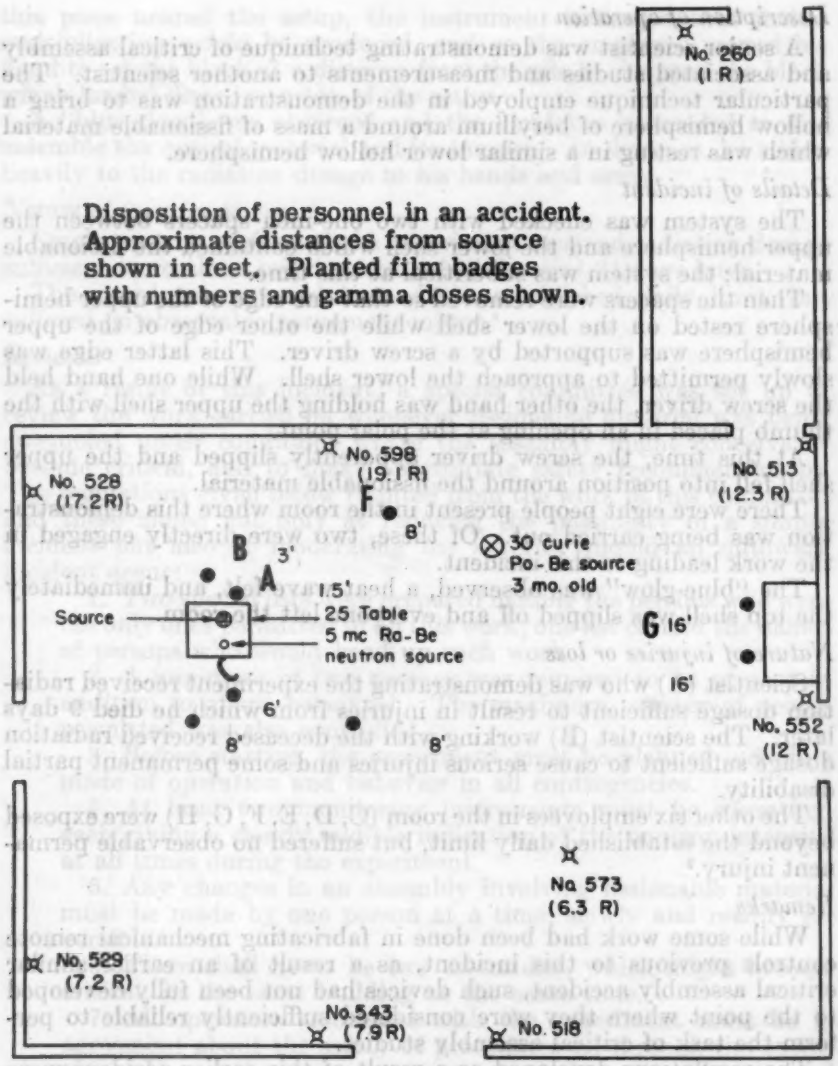
Remarks

While some work had been done in fabricating mechanical remote controls previous to this incident, as a result of an earlier similar critical assembly accident, such devices had not been fully developed to the point where they were considered sufficiently reliable to perform the task of critical assembly studies.

The regulations developed as a result of this earlier accident were considered adequate but, as was demonstrated, depended on the fallibility of individuals observing them. Immediately following this incident, all such work was stopped until mechanical remote control devices could be designed and fabricated to carry out critical assemblies.

Since the introduction of these remote assembly devices, there have been no incidents which resulted in excessive exposure to personnel. It should further be pointed out that the development of reliable remote control devices permitted critical studies, knowingly marginal, that would not have been attempted manually and thus permitted extended scientific research in such matters.

[5] "The Annals of Internal Medicine," vol. 36, part I, February 1952, published by the American College of Physicians, describes the medical aspects of this incident (cases 3 through 10).



Disposition of personnel in an accident. Approximate distances from source shown in feet. Planted film badges with numbers and gamma doses shown.

CRITICALITY RESULTS FROM ERROR IN CALCULATIONS

Los Alamos, N. Mex., April 18, 1952:

Nature of incident

A fissionable material assembly, remote from personnel, inadvertently was made supercritical.

Description of operation

Two stacks of fissionable disks were being built up stepwise, to give a slightly subcritical assembly with the two stacks brought together by remote control. The individual stacks were built up by hand in fixed assemblies and the two stacks brought together only by remote mechanisms.

Details of incident

After two members of the operating crew calculated from previous steps that one more disk could be added safely (they thought), the disk was added and, with attempted caution, the system was assembled remotely. Radiation indicators went off scale, actuating scrams, neutron counters jammed, and a puff of smoke was observed on the television viewer. Within three to five minutes indicators and counters returned to operating ranges.

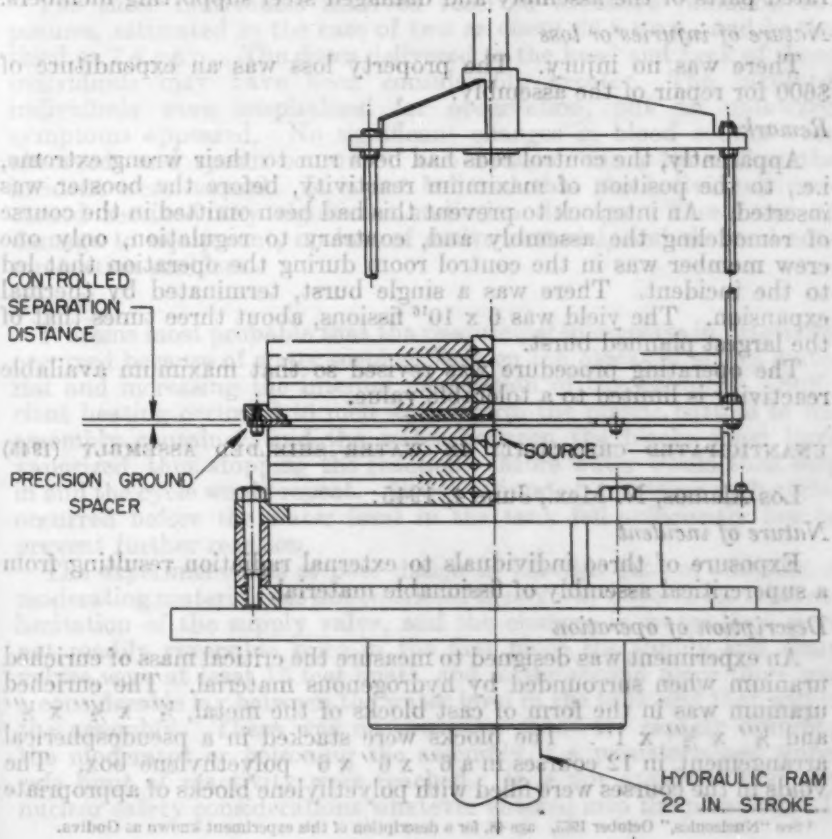
Nature of injuries or loss

There was no injury, no loss of material, no damage to facilities, and negligible loss of operating time.

Remarks

The crew members who checked safety of the final addition of fissionable material made the same algebraic error. The error would have been detected if data had been plotted as required by operating rules. Also, it was determined subsequently that the assembly rate of the system exceeded the maximum established by regulation. It is believed that there was just one radiation burst, terminated by thermal expansion, with a yield of $1.—2 \times 10^{16}$ fissions.

Existing operating regulations were reemphasized.



A criticality test assembly.

SUPERCRITICALITY EXPERIMENT

Los Alamos, N. Mex., Feburary 3, 1954.

Nature of incident

A fissionable material assembly, remote from personnel, inadvertently was made excessively supercritical.

Description of operation

The incident occurred in the course of an extensive study of the properties of supercritical radiation bursts produced by an assembly of fissionable metal. This study involved operations of a type that the normal regulations are designed to prevent, so was covered by a specific procedure. A reference check of critical conditions preceded each supercritical burst.[6]

Details of incident

To attain rapidly sufficient power for a delayed critical check, it was customary to set control rods at the position of minimum reactivity and insert a reactivity booster in the form of a fissionable metal slug. This time, when the booster was inserted, radiation indicators and the assembly temperature recorder went off scale (to return in a few minutes), and scrams were actuated. The resulting shock separated parts of the assembly and damaged steel supporting members.

Nature of injuries or loss

There was no injury. The property loss was an expenditure of $600 for repair of the assembly.

Remarks

Apparently, the control rods had been run to their wrong extreme, i.e., to the position of maximum reactivity, before the booster was inserted. An interlock to prevent this had been omitted in the course of remodeling the assembly and, contrary to regulation, only one crew member was in the control room during the operation that led to the incident. There was a single burst, terminated by thermal expansion. The yield was 6×10^{16} fissions, about three times that of the largest planned burst.

The operating procedure was revised so that maximum available reactivity is limited to a tolerable value.

UNANTICIPATED CRITICALITY IN WATER SHIELDED ASSEMBLY (1945)

Los Alamos, N. Mex., June 4, 1945:

Nature of incident

Exposure of three individuals to external radiation resulting from a supercritical assembly of fissionable material.

Description of operation

An experiment was designed to measure the critical mass of enriched uranium when surrounded by hydrogenous material. The enriched uranium was in the form of cast blocks of the metal, ½″ x ½″ x ½″ and ½″ x ½″ x 1″. The blocks were stacked in a pseudospherical arrangement in 12 courses in a 6″ x 6″ x 6″ polyethylene box. The voids in the courses were filled with polyethylene blocks of appropriate

[6] See "Nucleonics," October 1955, page 48, for a description of this experiment known as Godiva.

dimensions. The polyethylene box was supported by a 2-foot high stool within a 3-foot cubical steel tank. The tank had a 2-inch opening in the bottom through which it could be filled and drained by means of supply and drain hoses attached to a ¾-inch tee. The opening in the tank was fitted with a shutoff valve, as was the drain hose. A polonium-beryllium source of about 200 mc. strength was placed on top of the assembly. A fission chamber and a boron proportional counter were used to follow the experiment.

Details of incident

The immediate supervisor was absent from the scene when the experiment was begun. According to one of the operators, the water level was raised above the polonium-beryllium source with the supply valve nearly full open. At this point, a slight increase in counting rate was observed, which corresponded with what had been observed previously when the source alone was immersed in water. A few seconds later the counting rate began to increase at an alarming rate. At this point the supervisor returned and walked to within 3 feet of the tank and noted a blue glow surrounding the box. Simultaneously the two operators were hastily closing the supply valve and opening the drain valve. The building was then evacuated.

Nature of injuries or loss

The three individuals involved received excessive radiation exposures, estimated in the case of two as about 66.5 r.e.p., and in the third as 7.4 r.e.p. The doses delivered to the head and neck of these individuals may have been considerably greater. The involved individuals were hospitalized for observation, but no untoward symptoms appeared. No significant changes in blood counts were observed, and sperm counts on one occasion some time after the incident were normal. It is not believed that the individuals concerned received any significant radiation damage. There was no damage to equipment, no loss of active material, and no local contamination problem.

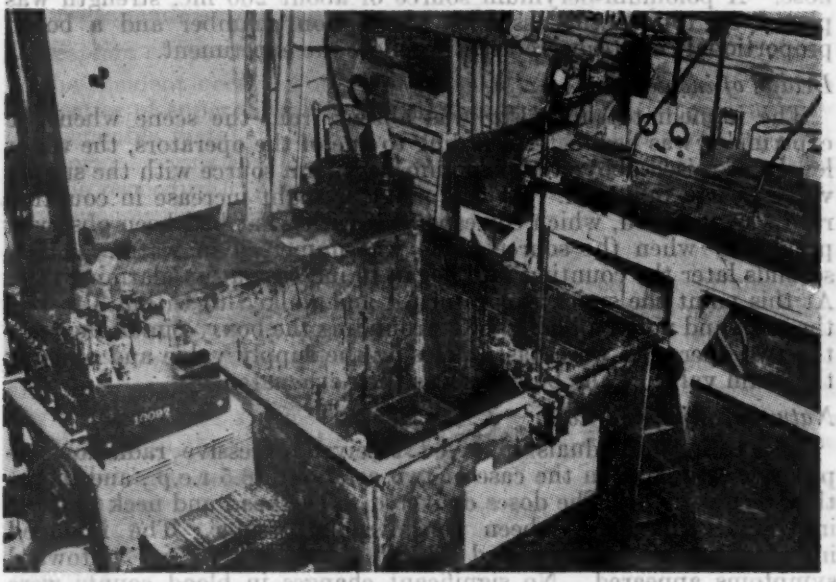
Remarks

It seems most probable that the unanticipated increase in reactivity occurred because of water seeping between the blocks of active material and increasing the internal moderation of the assembly. Sufficient heating occurred to melt and deform the plastic bottom of the assembly container, and the water between the blocks must have vaporized, thus stopping the reaction. More water would then seep in and the cycle would repeat. It was estimated that three such cycles occurred before the water level in the tank fell sufficiently low to prevent further reaction.

The experiment was of poor design in that the rate of addition of moderating material was not restricted in any way beyond the inherent limitation of the supply valve, and the changes in water level were not readily reversible since in the first place the supply and drain valves were at least 15 feet apart, and in the second place there was a considerable lag between the water level in the tank and that within the assembly. There was no provision made for rapidly dumping the moderator or poisoning the assembly if a predetermined upper safe limit of reactivity were reached. It is not apparent that any nuclear safety considerations whatever entered into the planning. It

was the opinion of the experimenters that criticality would not be reached during this run.

While no further experiments of this specific type were performed, similar experiments after 1946 were carried out with remote control systems without exposure to personnel.



Test equipment for water shielded assembly.

SCRAM MECHANISM CAUSES CRITICALITY

Los Alamos, N. Mex., March 20, 1951.

Nature of incident

A fissionable material assembly, remote from personnel, inadvertently was made supercritical.

Description of operation

Interactions between two masses of fissionable material in water were measured at progressively decreasing horizontal separations. Remotely controlled operations established the desired horizontal separation of the two components and flooded the system.

Details of incident

After the final measurement, the system was "scrammed" (a rapid disassembly mechanism was actuated). Safety monitor indicators went off scale, neutron counters jammed, and the television viewer indicated steaming. Within a few minutes, indicators and counters returned to operating ranges and indicated a rapid decay of radiation.

Nature of injuries or loss

There was no injury, no loss of material, and no damage to facilities.

Remarks

Unlike normal slow disassembly, the scram rapidly raised one component vertically instead of horizontally separating the two

masses. Subsequent tests showed that the center of reactivity of the movable component was below that of the stationary unit thus shortening the distance between them as the movable unit rose to the level of the stationary unit. Furthermore, the movable unit when rapidly raised through the water swung toward the stationary unit (Bernoulli effect).

There probably were several radiation bursts, each stopped by bubble formation in the water. The total yield was about 10^{17} fissions.

"Tangential scrams" were outlawed for future designs. All assembly machine design must be reviewed by several persons rather than by the work of an individual.

RADIATION EXCURSION IN A PLUTONIUM NITRATE SOLUTION CRITICAL ASSEMBLY

Hanford, Wash., November 16, 1951:

Nature of incident

An inadvertent super criticality of a spherical plutonium nitrate reactor when a safety rod was withdrawn too rapidly during a test.

Description of operation

A critical mass program was underway. A prime consideration of this program was the review of chemical separation plant operations from the standpoint of nuclear safety. An attempt was made to determine the maximum safe mass of plutonium for each part of the processing equipment. To this end criticality experiments were performed for several container geometries and process reagent concentrations. The fuel consisted of solutions of plutonium nitrate and the container geometries studied were tamped cylinders and tamped and bare spheres of different sizes.

In the course of the criticality program it became apparent that it would be desirable to determine experimentally the critical mass of a hemispherical shape.

Details of incident

As the program had called for a series of experiments in bare spherical reactors, it was decided to make this measurement by half-filling an available sphere and adjusting the concentration to obtain criticality. This was obtained in a spherical segment slightly larger than a hemisphere in a nominal 20-inch diameter sphere. Three additional critical points were found as the fuel was diluted and greater fractions of the sphere volume filled. The last critical point reached was in a volume 88 percent of the full sphere. As the critical concentration of the sphere was predictable, it was decided to make the final dilution for the full sphere as closely as possible. This required that the total fluid volume be known quite accurately. The method of making this measurement was to add the remaining fuel to the reactor and to determine the total volume by means of the reactor sight glass which gave an accurate measure of the fluid volume. The control and safety rods were inserted and were known to be sufficiently strong to easily override the reactivity of the excess fuel addition. The volume measurement was done carefully and without incident or significant increase in neutron level. Then, instead of draining the reactor for concentration change, an attempt was made to determine where criti-

cality might occur on the rods. As the total strength of the safety rod was known, it was thought that some additional information as to the required dilution could be determined by this measurement. The control rod was pulled first with very minor reactivity effect. Following this, the safety rod was withdrawn intermittently at high speed (2.3 inches/second). A waiting period for the delayed neutron effect of about 15 seconds was made just prior to the incident. This was too short a time to determine whether or not the assembly was critical. The operators next heard the safety controls actuate, instrument indicators moved off scale, scalers jammed, and the most startling manifestation was that of the breakdown of "counters" playing back through the public address system. The portable "Juno" in the control room was off scale. Presumably, a further rod withdrawal had been made.

An important effect to be considered is the production of gases in the reactor fuel. These gases are formed by the disassociation of the fuel caused by the ionization resulting from stopping the charged particles in the fuel. Most of the ionization results from the fission fragments, of course. The gas production is important in two respects. First, the energy absorbed in the gas formation is not measured in the temperature rise of the fuel; secondly, the formation of gases in the fuel may cause an expansion of the fuel. This expansion would result in density and volume changes in the fuel which could be very important.

That gas was formed during the incident is evident from the resulting contamination of the reactor room and known loss of fuel. The temperature of the fuel was well below boiling, yet a small amount of fuel was sprayed through the gaskets of the reactor assembly. These gaskets sealed a volume of air of about 18 liters above the fuel level prior to the incident. Pressures considerably in excess of atmospheric must then have existed in the assembly during the incident.

In order to estimate the manner in which the incident took place, the probable actions of the personnel and apparatus machinery involved must be analyzed. The first item to be noted is that the operator had been removing the safety rod from the reactor at high speed prior to the incident. At least partly because of the insenitive scales on which the instruments were set at the time the operator was watching, the operator was not cognizant of the impending runaway. Therefore, it seems likely that the safety rod was given another pull at high speed of a duration similar to the preceding pulls.

Nature of injuries or loss

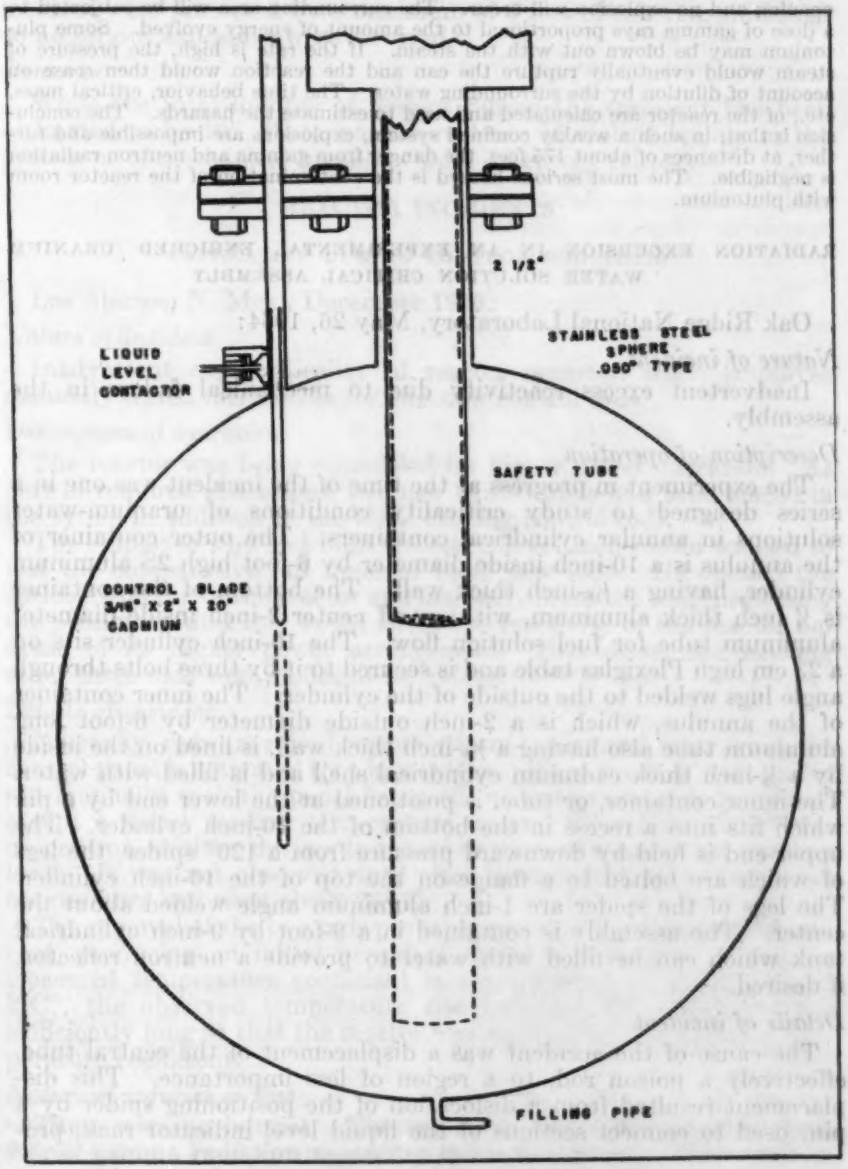
There were no injuries. The building was successfully decontaminated except for the test room and assembly. Before decontamination of this area was completed, a fire occurred and subsequently the building was abandoned (see p. 51).

Remarks

Emphasis must be placed on the fact that the incident was the direct result of the rapid withdrawal of a strong poison from the reactor. Increasing the reactivity at this rate allowed the system to become promptly critical before the power level had increased sufficiently to actuate the scram device. Short periods were then obtained in a time interval which was short compared to that necessary for the mechanical safeties to stop the reaction. Safe reactor design requires

that no mechanism be employed which will allow the rapid withdrawal of a strong poison from the system, to eliminate possible errors in judgment on the part of the operators.

An interesting result of the analysis is the extremely unfavorable change in geometry resulting from fuel expansion in the partially filled sphere. Had the sphere been full in this incident so that the fuel expansion immediately expelled fuel from the sphere, no incident of this magnitude could have occurred. Extreme caution is indicated in experiments involving such partially filled geometries.



A schematic diagram of the reactor assembly.

The above event was accurately anticipated in the hazards study prepared 2 years previously, as follows:

In the design of the apparatus to be used in plutonium critical mass experiments considerable attention was given to safety features. This report examines the hazard which would result in the extremely unlikely event that all of the safety devices failed to operate either by accident or sabotage. The reactor is a cylindrical can filled with a water solution of plutonium tetranitrate and immersed in a tank of water. If it is made supercritical, energy is produced in the solution at a rate proportional to the degree of supercriticality. If the rate is low, the solution will heat to boiling and water will be boiled off until the remaining solution becomes subcritical. In such a case the steam will be blown out through an opening and no explosion will occur. The surrounding area will be subjected to a dose of gamma rays proportional to the amount of energy evolved. Some plutonium may be blown out with the steam. If the rate is high, the pressure of steam would eventually rupture the can and the reaction would then cease on account of dilution by the surrounding water. The time behavior, critical mass, etc., of the reactor are calculated and used to estimate the hazards. The conclusion is that, in such a weakly confined system, explosions are impossible and further, at distances of about 175 feet, the danger from gamma and neutron radiation is negligible. The most serious hazard is the contamination of the reactor room with plutonium.

RADIATION EXCURSION IN AN EXPERIMENTAL ENRICHED URANIUM WATER SOLUTION CRITICAL ASSEMBLY

Oak Ridge National Laboratory, May 26, 1954:

Nature of incident

Inadvertent excess reactivity due to mechanical failure in the assembly.

Description of operation

The experiment in progress at the time of the incident was one in a series designed to study criticality conditions of uranium-water solutions in annular cylindrical containers. The outer container of the annulus is a 10-inch inside diameter by 6-foot high 2S aluminum cylinder, having a 1/16-inch thick wall. The bottom of the container is 1/4 inch thick aluminum, with an off center 2-inch inside diameter aluminum tube for fuel solution flow. The 10-inch cylinder sits on a 23 cm high Plexiglas table and is secured to it by three bolts through angle lugs welded to the outside of the cylinder. The inner container of the annulus, which is a 2-inch outside diameter by 6-foot long aluminum tube also having a 1/16-inch thick wall, is lined on the inside by a 1/8-inch thick cadmium cylindrical shell and is filled with water. The inner container, or tube, is positioned at the lower end by a pin which fits into a recess in the bottom of the 10-inch cylinder. The upper end is held by downward pressure from a 120° spider, the legs of which are bolted to a flange on the top of the 10-inch cylinder. The legs of the spider are 1-inch aluminum angle welded about the center. The assembly is contained in a 9-foot by 9-inch cylindrical tank which can be filled with water to provide a neutron reflector, if desired.

Details of incident

The cause of the accident was a displacement of the central tube, effectively a poison rod, to a region of less importance. This displacement resulted from a dislocation of the positioning spider by a pin, used to connect sections of the liquid level indicator rack, pro-

truding beyond the side of the rack and engaging a leg of the spider as the indicator was raised. Removing the compressional force from the top of the central tube allowed it to fall against the inside of the 10-inch cylinder. Although the displacement was small, it was sufficient to cause a large increase in the effective neutron multiplication.

Nature of injuries or loss

The safety system apparently operated normally and the reaction was stopped automatically. All personnel in the building during the incident were protected by a minimum of 5 feet of concrete shielding, so no serious exposures were incurred.

Remarks

While the total number of fissions during the transient has been estimated to be 10^{17}, there was no evidence of violent boiling in the system or of mechanical breakdown due to energy release.

REACTOR INCIDENTS

CRITICALITY DURING CONTROL ROD TESTS

Los Alamos, N. Mex., December 1949:

Nature of incident

Inadvertent supercriticality of reactor occurred when employee manually tested mechanism for two new control rods.

Description of operation

The reactor was being remodeled for higher power operation. As part of required alterations, two new control rods had been placed in the sytem in addition to the three existing control rods.

The employee who had built the rod control mehcanism wanted to test the comparative fall times of these new rods. He opened the enclosure on top of the reactor and manually lifted the rods, neglecting the possibility that this would affect the reactivity of the reactor because of its higher power arrangement. Heretofore, the existing other three rods were sufficient for safety.

Details of incident

Normally, rods are raised remotely from the control room when the control panel is activated by a key switch. Since the rods were pulled out manually with the panel being off, no equipment was turned on except a direct reading temperature meter. Therefore, there were no neutron-sensitive devices to record or warn of a rise in the neutron level. It was not observed until after the incident that the reactor temperature had risen about 25° C.

The removal of the two rods probably gave a Δ K of about 0.86 percent, producing an initial period of about 0.16 second. Since the measured temperature coefficient is approximately —0.034 percent k/C°, the observed temperature rise indicates the rods were out sufficiently long so that the reactor was stopped by the negative temperature coefficient.

Nature of injuries or loss

There were no injuries. The employee doing the work received 2.5r of gamma radiation according to his film badge. There was no damage done to the reactor and no loss of active material.

Remarks

To avoid any similar incident in the future, the use of the key to the locked enclosure, above the reactor, containing the rod mechanism was restricted to two senior individuals in the group.

In addition to this administrative arrangement, a special device was added to the rod control mechanism. This device was used whenever the enclosure had to be left open for any period of time. The special device built was a pivoted plate provided with a slide which would permit only one control rod to be moved at a time after the plate was locked into position on the top of the control rods.

SUDDEN INCREASE IN REACTIVITY DURING CONTROL ROD TESTS

Argonne National Laboratory, Lemont, Ill., June 2, 1952:

Nature of incident

Manual withdrawal of a control rod from a reactor caused an accidental supercriticality. Four persons were overexposed but apparently were not injured.

Description of operation

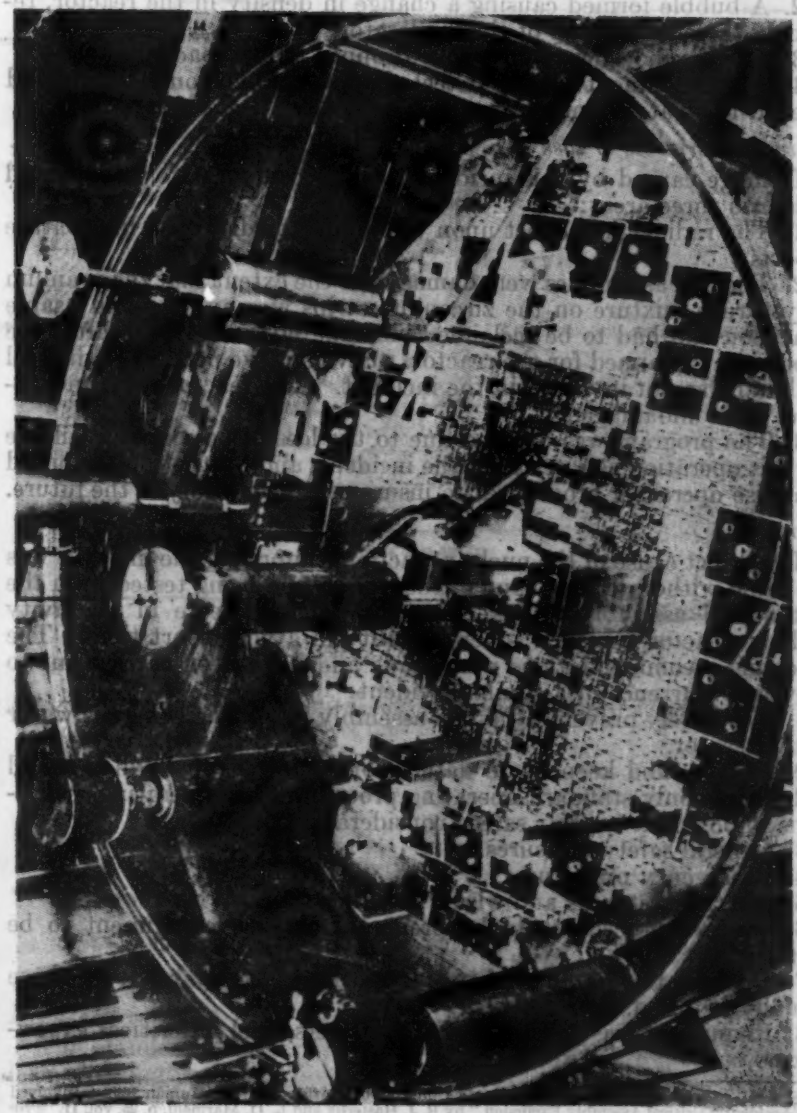
The operation being conducted was the comparison of a series of newly manufactured control rods. The reactor had been operated with the standard control rod. It was then shut down by inserting all control rods and draining the water moderator, a standard safe method of shutting down the reactor when core changes are to be made. The standard rod was removed and the first of the series of control rods to be tested was inserted.

The reactor was filled with water with the test control rod fully in and the standard type control rods fully inserted. Withdrawing of one of the standard control rods, 32 cm, caused the reactor to become critical and the power was leveled off while the desired measurements were made. The control rod was then reinserted into the original "in" position.

Details of incident

With the water still in the reactor, the four members of the crew then went into the assembly room for the purpose of replacing the control rod which they had just tested. The group leader went up on the platform, reached out with his right hand and started to pull out the tested rod. As soon as he had withdrawn it about 1 foot, the center of the reactor emitted a bluish glow and a large bubble formed. Simultaneously, there was a muffled explosive noise. The group leader let go of the control rod which he was removing and it fell back into position. The crew left the assembly room immediately and went to the control room.

The reactor became supercritical because the test rod being removed by the leader was highly effective in suppressing the chain reaction when fully inserted. But, as it was being removed, a point was reached when the reactor was critical even with the standard type rods fully inserted. In removing this rod, the reactor passed through the critical into the prompt critical stage. This would not have occurred if water had not been in the reactor assembly, since this thermal reactor was dependent upon water to moderate the neutrons from the fast energy level to the thermal energy level and the fission process can only be supported by thermal energy neutrons.



Top view of test reactor.

After this supercriticality was reached, several reactions took place, any one of which could have contributed to immediately shutting the reactor down:

1. Part of the uranium polystyrene fuel mixture expanded, displacing the water.
2. A bubble formed causing a change in density in the reactor, reducing the effectiveness of the moderator.
3. The group leader immediately dropped the rod back into place.
4. The instrument circuits detected a level of neutron intensity and opened the water dump valve.

Nature of injuries or loss

Damage caused by this incident appears comparatively slight and falls into three areas:

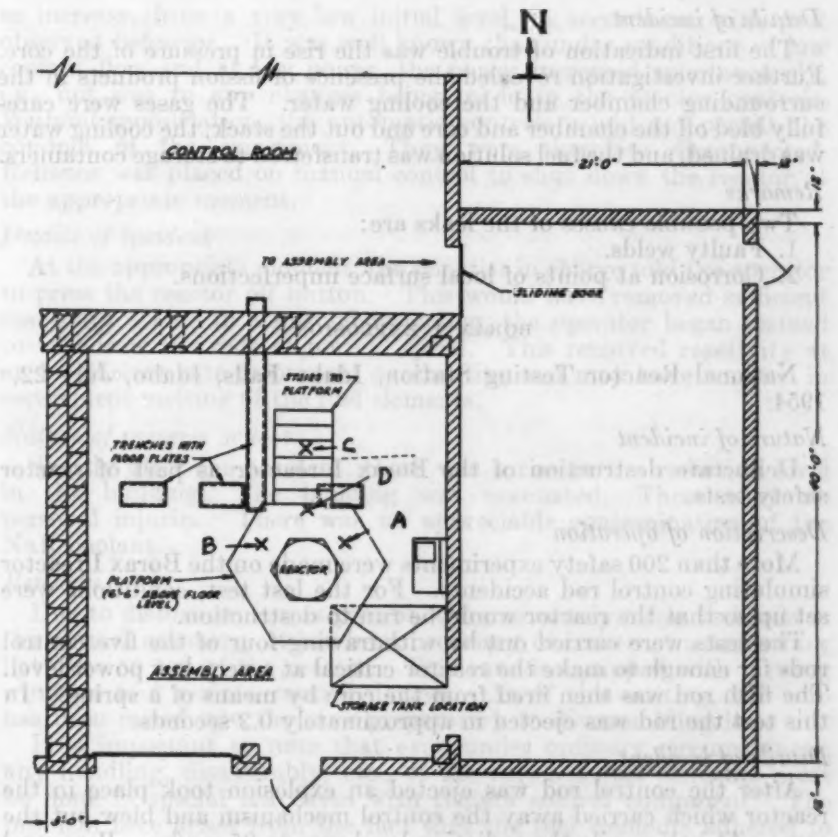
1. The radiological effect upon the victims is discussed in separate reports.[7]
2. The fuel assemblies were damaged to the extent that the uranium polystyrene mixture on the zirconium strips was no longer in usable condition and had to be reclaimed immediately rather than after the experiments planned for the reactor. Seventy-five percent of the fuel on hand was not involved in the incident. The reactor tank and fixtures were undamaged.
3. The program was delayed due to the loss of personnel available for this operation as a result of the incident, and by the time required to revise operating procedures to insure complete safety in the future.

Remarks

The direct cause of the nuclear reaction comprising the incident was the rapid withdrawal by hand of the control rod being tested from the water-filled assembly. This effected a large increase in reactivity and the reactor achieved supercriticality in a very short time. The following recommendations were made and have been carried out to prevent occurrence of a similar incident:

1. Absolutely prevent access to assembly room when there is water in the reactor.
2. Prepare and keep up to date an operating manual which would include not only standard operating procedures but operating restrictions imposed by nuclear safety considerations.
3. General safety measures.
4. Emergency procedures.
5. Control diagrams and wiring identification.
6. Written procedures to be prepared for each experiment to be performed.
7. Restrict the number of people in the assembly room to those actually required.
8. Require at least two qualified staff personnel on critical experiments.

[7] See ANL 4971 and "Physical Dosimetry and Clinical Observations on Four Human Beings Involved in an Accidental Critical Assembly Excursion," by R. J. Hasterlik and L. D. Marinelli, p. 25, vol: 11, "Proceedings of the International Conference on the Peaceful Uses of Atomic Energy" (held in Geneva, Aug. 8-20, 1955).



Layout of reactor showing position of crew at time of the accident.

REACTOR FUEL LEAK [8]

North Carolina State College, May 1955:

Nature of incident

The stainless steel core of a water boiler type reactor developed a leak allowing fuel solution to leak into the surrounding chamber and the cooling water.

Nature of operations

This incident occurred in a university reactor being operated for research and training purposes.

[8] This incident occurred at a non-AEC location but is included as an example of a type of reactor failure. No one was injured or exposed to radiation.

Details of incident

The first indication of trouble was the rise in pressure of the core. Further investigation revealed the presence of fission products in the surrounding chamber and the cooling water. The gases were carefully bled off the chamber and core and out the stack, the cooling water was drained, and the fuel solution was transferred to storage containers.

Remarks

Two possible causes of the leaks are:

1. Faulty welds.
2. Corrosion at points of local surface imperfections.

BORAX I EXPLOSION

National Reactor Testing Station, Idaho Falls, Idaho, July 22, 1954:

Nature of incident

Deliberate destruction of the Borax I reactor as part of reactor safety tests.

Description of operation

More than 200 safety experiments were made on the Borax I reactor simulating control rod accidents. For the last test, conditions were set up so that the reactor would be run to destruction.

The tests were carried out by withdrawing four of the five control rods far enough to make the reactor critical at a very low power level. The fifth rod was then fired from the core by means of a spring. In this test the rod was ejected in approximately 0.2 seconds.

Details of incident

After the control rod was ejected an explosion took place in the reactor which carried away the control mechanism and blew out the core. At half a mile the radiation level rose to 25 mr/hr. Personnel were evacuated for about 30 minutes.

Nature of injuries or loss

No one was injured and the destruction of the reactor was part of the cost of the experiment.

Remarks

Although it was greater than anticipated, the explosion was comparable to that which could be produced by only a few pounds of TNT. It is believed that a cause of the explosion was the chemical reaction of aluminum and water.

EBR INCIDENT

Idaho Falls, Idaho, November 29, 1955:

Nature of incident

Overheating of reactor core which may have resulted in partial melting of fuel elements.

Description of operation

The experimental breeder reactor was undergoing a series of experiments. This particular experiment consisted of permitting the power

to increase, from a very low initial level, in accordance with past observed behavior. It was well known that under conditions of low coolant flow and at low power, the power increased spontaneously, i.e., not due to any changes being made to the reactor controls. Without modification, the automatic controls would not permit the conduct of the experiment. They were therefore disconnected. Reliance was placed on manual control to shut down the reactor at the appropriate moment.

Details of incident

At the appropriate moment, the scientist in charge told the operator to press the reactor off button. This would have removed sufficient reactivity. Due to a misunderstanding, the operator began instead to withdraw the rods at normal speed. This removed reactivity at an insufficient rate to prevent overheating and may have resulted in consequent melting of the fuel elements.

Nature of injuries or loss

Shortly after the accident, there was a rise in the radiation level in the building. The building was evacuated. There were no personal injuries. There was no appreciable contamination of the NaK coolant.

Remarks

Due to distortion, it was possible to remove only a few fuel rods in the normal manner. It has been necessary to construct a temporary hot cave on top of the reactor. This cave is equipped with viewing windows and remote control devices. As of this writing, the core has been raised into the cave preparatory to disassembling it.

It is important to note that even under ordinary circumstances, any handling, disassembly, etc., of the enriched fuel elements must be done in special hot caves with remote control equipment. The problem here arises from the fact that the fuel elements adhered to the bottom plate, thus making it necessary to raise the whole core structure as a unit. The system was designed to handle one fuel rod at a time and is not capable of lifting the entire core and transferring it to the regular remote handling facility. Thus, it was necessary to rig a remote handling facility on top of the reactor so the regular overhead crane could be used to raise the core.

Contamination Incidents

RADIUM CONTAMINATION INCIDENT

Argonne National Laboratory, Lemont, Ill., June 13, 1952:

Nature of incident

A radium sulphate capsule broke and contamination was tracked around laboratory.

Description of operation

A 50-mg. radium sulphate source was used to calibrate pocket meters in a laboratory.

Details of incident

During the course of the work, the capsule broke in some unexplained manner and approximately 10 milligrams of radium sulphate were released.

The material was spread through three wings of the building and was further spread by being tracked around on the shoes of personnel who were in the building and persons who entered the building (without instructions) to assist. The importance of the incident is due instead to its effect upon the instrumentation in the building, which depends on low background for satisfactory work.

The front end of the building remained usable; the first floor was not seriously affected, but two wings and the shop required decontamination. The ventilation in the building remained shut off although the south windows of the building were opened up.

Nature of injuries or loss

There were no injuries. There were no hazardous concentrations at any location.

Remarks

The shops had been engaged in fabricating an improved device for calibrating pocket meters which were scheduled for delivery in about 2 weeks. The new standard source will use canned cobalt rather than radium. Had the new device been in use, such an incident could not have occurred.

NEUTRON SOURCE FAILURES (TWO)

Ames, Iowa, July 1951 to August 1952:

Nature of incident

There have been two serious and other minor cases of neutron sources leaking, causing contamination to laboratory buildings.

Description of operations

Sealed metal capsules, containing a neutron source (such as polonium-beryllium), are used in laboratories for neutron experiments and for instrument calibration.

Details of incident

Cases have occurred where the capsule failed permitting the release of polonium. In two of these the contamination spread through the entire building.

Nature of injuries or loss

Several people received overexposure but none serious enough to be hospitalized.

The loss due to decontamination, and loss of the use of the building for that time, amounted to over $30,000 in each of the two serious cases.

Remarks

Laboratories using radioactive material should consider the possibility of a release and plan for this in the design of the building. Compartmentalization and use of materials that can easily be decontaminated or discarded will greatly reduce the costs of an accident.

SEWER CONTAMINATION INCIDENT

Ames, Iowa, July 1951 to August 1952:

Nature of incident

Discharge into sewer of waste containing greater quantities of radioactivity than anticipated.

Description of operation

Metallic thorium was being produced from thorium nitrate tetrahydrate. During an early stage of the processing, a filtrate containing traces of thorium in the form of the nitrate and oxalate was released to the sewer which connected to the city sewerage system. This operation had been carried out for over a year.

Details of incident

At the time disposal to the sewer was decided upon, it was believed that this waste had a very low level of radioactivity. A chemical method of reducing this still further and ensuring that no release would be made to the sewer had been developed and was being engineered to the necessary scale for this operation when it was discovered that, due to a change in feed material supplied to the laboratory, considerable quantities of mesothorium were being discharged in the filtrate. Mesothorium is one of the daughter products of thorium decay.

While mesothorium gives off gamma and beta radiation, its principal hazard as a waste product is due to alpha activity of its decay products.

All the sewage was processed in a "complete treatment" sewage plant. Such a plant discharges a waste liquid effluent and produces dry sludge which is used for fertilizer. The treatment process was found to remove mesothorium very effectively so that the effluent water from the sludge disposal plant had negligible quantities of mesothorium in it. The dry sludge produced during this period had been spread on the city airport, municipal parkway, and the cemetery.

A thorough study of this incident disclosed that there was no hazard to the public or to the employees of the sewer plant even though the radiation levels of the sewer discharges were higher than had been anticipated.

Nature of injuries or loss

None.

Remarks

This incident illustrates the necessity of extreme care in the identification and control of radioactive wastes discharged into public sewer and drainage systems.

EXCESSIVE INTERNAL DOSE OF PLUTONIUM

Hanford, February 16, 1955:

Nature of incident

An employee received 1½ times the maximum permissible limit of plutonium in the body.

Description of operation

Employee was doing semiroutine maintenance work on plutonium contaminated equipment.

Details of the incident

At the time of the operation, the employee was wearing protective clothing and an assault mask. No definite cause can be assigned for the inhalation of the radioactive material. The mask was tested and found to be in proper operating condition. The possibility of improper

adjustment of the mask, allowing inleakage around the facepiece, is considered the most likely cause. Radiological monitoring disclosed that the employee's clothing and some skin surface were contaminated. Routine biological tests disclosed a deposition of plutonium about 1½ times the recommended permissible limit.

Nature of injuries or loss

The employee has not missed any work and has suffered no detectable ill effects to date. It is not expected that any adverse effects will develop in the future because there is believed to be a margin of safety beyond the official permissible limit sufficient to make his exposure harmless. The employee is now assigned to work which does not involve radioactive material.

Remarks

This was the first case in the 12-year history of this facility in which an employee has received an internal dose of plutonium greater than the recommended limit.

FUME INCIDENT

Hanford, February 5, 1953:

Nature of incident

A pressure surge in a system in which a highly radioactive material is dissolved in a solvent.

Description of operation

Operation involves the use of acids and organics for the separation of metals from a highly radioactive solution.

Details of incident

A pressure surge was apparently caused by the contacting of solvent with concentrated nitric acid. Brown fumes (nitrogen oxide) were observed coming from the cell at the same time that instruments indicated operating difficulties. A quick radiation check indicated a high level of activity. The entire exclusion area was evacuated.

Nature of injuries of loss

There was no injury or unusual exposure to radiation hazard by personnel during the incident. Decontamination required work in high-level fields and resulted in some exposures to personnel. Investigation indicated no overexposure.

Remarks

Detailed engineering and process changes were carried out to prevent a repetition of this incident.

CONTAMINATION OF AIR IN A CHEMICAL PLANT

Chemical Processing Plant, Idaho Falls, January 10, 1955:

Nature of incident

Air contamination of a chemical plant building due to an operational incident.

Description of operation

Some highly radioactive liquid had overflowed into a sump which had been provided for this type of situation. An operator began to transfer the material back to the system by means of a steam jet.

Details of incident

Radiation contamination was spread through several parts of the plant as the result of continued jetting of the sump after all the liquid had been transferred from it. Jetting was continued because the sump indicator light erroneously showed that liquid still remained in the sump and the operator did not recognize the change in the sound of the jet as it started to suck air. The jet steam escaped from the tank through drain lines into several rooms where the contamination was indicated by constant air monitors. The health physics group ordered evacuation of the rooms and initiated investigation as to the cause.

The trouble was quickly discovered and eliminated. Another room experienced air contamination about 30 minutes later which may or may not have been from the same cause. Air activity dropped to safe level within less than 1 hour and work was resumed.

Nature of injuries or loss

After the incident, most of the men involved were immediately given nose checks and those with significant readings had urine samples taken. Several days later, all people in the building at the time of the incident were sampled. The results showed that no one had received serious exposure.

Remarks

Two important lessons can be learned from this incident:

1. The most routine type of operation can lead to a serious incident when dealing with highly radioactive material. Therefore, all possible eventualities should be considered and definite plans formulated to cope with them.

2. It is difficult for operators to understand all the complexities and hazards of modern plants. Compounding this problem is the operator's dependence on instruments which sometimes fail. The closest possible supervision must be employed.

UNH SOLUTION SPILL

Hanford, Wash., December 30, 1954:

Nature of incident

Over 1,500 gallons of uranyl nitrate hexahydrate solution spilled when a tank trailer overturned.

Description of operation

An intraplant transfer of UNH was being made in a tank trailer. Before starting out, the driver routinely tested the airbrakes and found that those on the trailer were not working. In spite of this, he decided to go ahead with the trip.

Details of incident

En route, he applied the tractor brakes to maintain control of the unit on a downhill grade. The trailer swerved left and right until it overturned.

Immediately after the spill, the road was blocked off. The fire department washed all the material from the road into a drainage ditch. This ground was dug up and removed for reworking. Not

only was a large percentage of the uranium recovered, but the radiation level was reduced to a point where no controls were necessary on the road. Within 4 hours after the accident the road was reopened.

Nature of injury or loss

Damage to the equipment, salvage, recovery, and loss of material cost approximately $59,000. No one was injured.

Remarks

The following factors seem pertinent:

1. Design of the tank trailer incorporated a high center of gravity and difficult front suspension with susceptibility to overturning, which had been overlooked when design was approved by AEC and contractor's safety departments.
2. Although the driver is a qualified heavy duty truck and trailer operator, this was his first trip with this trailer.
3. He was aware of the standard practice which prohibited use of defective equipment.
4. He also knew that delivery of the load was desired promptly.
5. He elected to go without trailer brakes, believing he could make the trip safely.

Action taken:

1. The operator has been disciplined for violation of an established safe operating practice.
2. The tank has been mounted on a 25-ton lowboy for increased equipment stability in over-the-road operation. Practical type and design of equipment for this work is being studied.
3. A relative material value will be declared on future movements.

FIRES

URANIUM SCRAP FIRE

Los Alamos, N. Mex., June 27, 1949:

Nature of incident

Fire involving pressed normal uranium turnings in drums.[9]

Description of operation

Uranium turnings received as scrap from machining operations were pressed into briquettes and sorted awaiting a casting operation which recovered about one-third the uranium in elemental form.

There were 51 drums stored outdoors and away from any building because of the pyrophoric characteristics of the turnings. Each drum contained about 500 pounds of normal uranium in the form of 3-pound disks, each 3½ inches in diameter and 1½ inches thick.

Details of incident

The fire was discovered and reported by inspectors who noticed a small amount of smoke, and one barrel was found to be on fire with a canvas tarpaulin covering the cans burning slowly. The fire department responded and the fire was attacked with a fine water spray. Thirty-one drums were removed from danger area before the intensity of the fire made it impracticable to move the others.

[9] This fire is typical of a number which have occurred.

After the removal of the drums had been carried out, each of the remaining ones were attacked individually with solid streams of water. With the use of pike poles and wrecking bars, the burning mass in each barrel was agitated, while the water was played on it. The extinguishment was finally accomplished after about 20 minutes' work on each of nine barrels.

Nature of injuries or loss

There were no injuries.

The dollar loss, though difficult to evaluate accurately, was modest and probably amounted to several hundred dollars.

Remarks

The remaining drums were filled with water and covered with ventilated tops. The current practice is to store the turnings in smaller drums (about 100 pounds) under oil or water and ship by truck to the recovery plant.

It was recognized that the hazard of fire presented a storage problem with respect to briquettes and accordingly the drums were stored out of doors and away from any building. Each drum was capped with a loose fitting lid to allow the escape of hydrogen gas generated by the reaction of any moisture present with the uranium metal. Submergence of the turnings under water or oil would reduce the fire risk, although such procedures must depend on the recovery requirements.

In fighting the fire, the firemen wore mechanical filter respirators in addition to their regular firefighting clothing; in accordance with standard procedure they worked from upwind. At the conclusion of the incident, careful monitoring found contamination only on the pike poles and wrecking bars; these were readily decontaminated and returned to service.

URANIUM CASTING FIRE

Los Alamos, N. Mex., December 9, 1952:

Nature of incident

Fire involving the casting of normal uranium.

Description of operation

A unique casting of more than 3,000 pounds of uranium metal was being carried out in a graphite mold placed in a micarta induction furnace. The charge metal in the form of large disks was premelted in the same furnace in a graphite crucible located above the mold.

Details of incident

This was the first such run and the first time a casting of this size had been attempted. The mold failed and the molten metal flowed to the bottom of the furnace where it flowed into the vacuum line. When the metal reached the vacuum line trap, it burned through and spilled onto the floor behind the furnace. However, not all of the metal flowed into this area; if it had done so, the uranium could have been covered with powdered graphite, thus excluding the air and extinguishing or reducing the rapid oxidation of the metal.

When the vacuum line trap was ruptured, this permitted a natural draft through the furnace. This draft, coupled with the reaction of

34434—59——19

the molten metal with the water from the sprinkler system and from the cooling coils of the furnace, produced hot flames above the furnace.

The fire was difficult to fight and while it was under control to the extent that the building and the general environment were never in jeopardy, the attention of standby firemen was required for several hours.

When the dismantling of the furnace was commenced 18 hours later, some glowing embers of uranium in the uranium oxide were still in evidence.

Nature of loss or injury

There were no injuries and the loss was limited to the furnace equipment, estimated at $1,200 to $1,500. All the uranium was recovered as oxide or metal. As a matter of interest, a duplicate furnace, located 2 feet from the furnace involved, showed no sign of damage.

Remarks

Considerable thought and planning took place before the run was started, since this was the first such operation and the graphite available for the mold was not of a size and quality that would have been preferred for this work.

The entire operation was planned so that the minimum number of personnel would be at the scene during the melting and casting operation. At the time the metal was poured, only one man was close to the operation and he had a clear exit which he immediately used.

Subsequent to this incident, many similar runs were made without difficulty.

A new and larger furnace was constructed which permitted the use of larger diameter molds. The mold that failed had been made to fit the old furnance and the mold wall thickness was limited by the furnace diameter. The larger new furnance permitted a thicker mold wall.

Subsequently, the availability of larger-sized graphite stock of a better quality permitted improved mold construction.

The sprinkler heads located directly over the large induction furnaces were removed as a consequence of this incident.

At the time of the incident, personnel were evacuated from the building to prevent their interference with fire control measures. General area monitoring showed no significant contamination other than the immediate vicinity of the spilled material.

FIRE IN A TRUCKLOAD OF URANIUM METAL

Near Kansas City, Mo., October 29, 1952:

Nature of incident

A truckload of solid pieces of uranium metal was involved in fire.

Description of operation

Solid pieces of uranium metal were being transported by truck between plants.

Details of incident

The truck was involved in a vehicular accident and fire resulted from rupture of the truck's gasoline tanks. The fire started to spread to the cargo which was in wooden crates. A local fire department responded but was instructed to use no water. The guards with the

truck had received such instructions. At one time, it was thought that such a fire could not be fought with water. The instructions had been changed but the two men concerned had not yet attended the training class.

The fire spread through most of the cargo prior to the arrival of an AEC contractor fire department which extinguished the fire with water.

Remarks

It is well established that uranium in finely divided form or in small pieces such as machine scrap is pyrophoric. Research is underway to determine basic information in the field of uranium pyrophoricity. It is uncertain whether massive uranium metal will sustain combustion but this fire proves that massive uranium must be protected against exposure to external fire. In the case of both scrap and massive metal the "ashes" (uranium oxide) can be recovered for reprocessing. But the loss can be much higher in machined metal due to the fabrication steps which have taken place. Radiation contamination from a normal uranium fire is negligible.

Final extinguishment of uranium truck fire.

SLUG FAILURE INCIDENT

Hanford, November 1, 1955:

Nature of incident

A fire occurred while removing a ruptured slug from a reactor.

Description of operation

A ruptured slug was stuck in a tube. Mechanical pressure was used to move it with some success. This was followed with a high pressure stream of water.

Details of incident

As the water washed the slug out of the tube, a flash of flame took place. The combustion products were picked up in the ventilation system and emitted from the stack.

Nature of injuries or loss

No one was injured. Decontamination work was necessary throughout the back of the reactor. Some of the surrounding countryside was slightly contaminated to a distance of several hundred feet.

Remarks

The exact cause of the fire is not known. It is suspected that a pocket of air ahead of the water picked up uranium dust.

PLUTONIUM FIRE [10]

Hanford, Wash., May 7, 1954:

Nature of incident

A fire involving a quantity of plutonium turnings.

Nature of operation

The turnings were loaded into combustible containers, which were placed in a plastic bag. The bag was then removed from the hood for heat sealing.

Details of the incident

The plastic bag was positioned in an electronic heat sealing unit while one of the operators donned an assault mask. This operator returned to adjust the sealing bar and observe the sealing. The second operator, without a mask, moved about 8 feet away and energized the sealing unit.

About halfway through the 6-second sealing cycle, the masked operator observed a growing brown spot on the plastic bag and white smoke inflating the normally deflated bag. He warned the other operator to shut off the sealer and they quickly left the immediate area of the burning material. The second operator donned a mask and warned five employees, working in the same area some distance away, of the hazards. The latter workers evacuated immediately.

The two operators returned to the turnings which were now burning on the floor—(NOTE.—It is not clear how the plastic bag dropped or fell to the floor, nor why the bag was not placed in a nearby hood.)—and tried to control the flame, using three small CO_2 extinguishers. Flames 2 to 3 feet high were observed. The extinguishers had little

[10] This is a typical example of the type of fire which occurs in plutonium operations. Several others have taken place.

or no effect and in a matter of minutes the fire burned itself out. The operators evacuated the space and aided the sealing of the space to prevent further spread of contamination.

Operations in this space were discontinued for about 3 weeks while decontamination activities were completed by the operating forces.

Nature of injuries or loss

The direct costs incurred in the decontamination amounted to approximately $20,000.

Remarks

The cause of the fire was not definitely determined. Plutonium chips are pyrophoric and fires should be anticipated in the design and procedures of all plutonium-chip operations. While the magnitude of the material loss may vary depending on recovery, the fire loss due to decontamination costs may be quite high, unless prior steps have been taken to suppress general contamination in the event of a fire.

Among other steps taken in this case was the elimination of combustible containers and process rearrangement so as to make it unnecessary to remove the material from the hood.

FIRE INVOLVING PLUTONIUM TURNINGS

Hanford, July 27, 1954:

Nature of incident

A fire in plutonium turnings in a laboratory hood.

Nature of operations

Some plutonium-metal turnings were being dissolved in nitric acid in a stainless steel pot. All of the turnings were placed in the pot and 500 ml of 70 percent HNO_3 and 200 ML of water were added. The water was added by 20 ML at a time.

Details of incident

The mixture was heated from 5 to 10 minutes on a standard laboratory hotplate, the hotplate was turned off, and the mixture had cooled for approximately 5 minutes when a flash and cloud of brown gas appeared within the hood. Sufficient pressure was exerted to force oxides of nitrogen and contamination to pass through the intake filters. Molten plutonium metal and/or oxide was scattered throughout the hood, starting a number of small fires. The pot containing the mixture was covered with a stainless-steel cover. The cover was set on the pot with bolts in place, the bolts were not fastened, the cover was vented through a length of tygon tubing to the hood sink. The exerted pressure blew the cover off and the pot was found in the sink. The negative air pressure differential in the hood is approximately 1 inch of water. The airflow of the hood is such that a complete change is made approximately every 4 minutes.

Nature of injuries or loss

There were no injuries.

Remarks

The definite cause of the fire was not determined, but two possibilities exist:

1. The metal turnings were not completely immersed in the solution, and as the turnings were dissolved they settled causing a friction spark.

2. The exposed metal turnings may have oxidized so rapidly that ignition may have occurred.

Either of the two could have caused the flash in the presence of hydrogen gas given off by addition of water to the solution.

FIRE IN PLUTONIUM CONTAMINATED WASTE

Hanford, Wash., December 4, 1951:

Nature of incident

A fire occurred in the contaminated storage area of a research building and communicated to the chemical laboratory exhaust hood filters and attic.

Description of operation

After the radiation burst, described on page 14, the entire building, with the exception of the test assembly room, had been successfully decontaminated and left in a neat and orderly fashion. Decontamination work was proceeding in the test assembly room and on the reactor control assembly.

Details of the incident

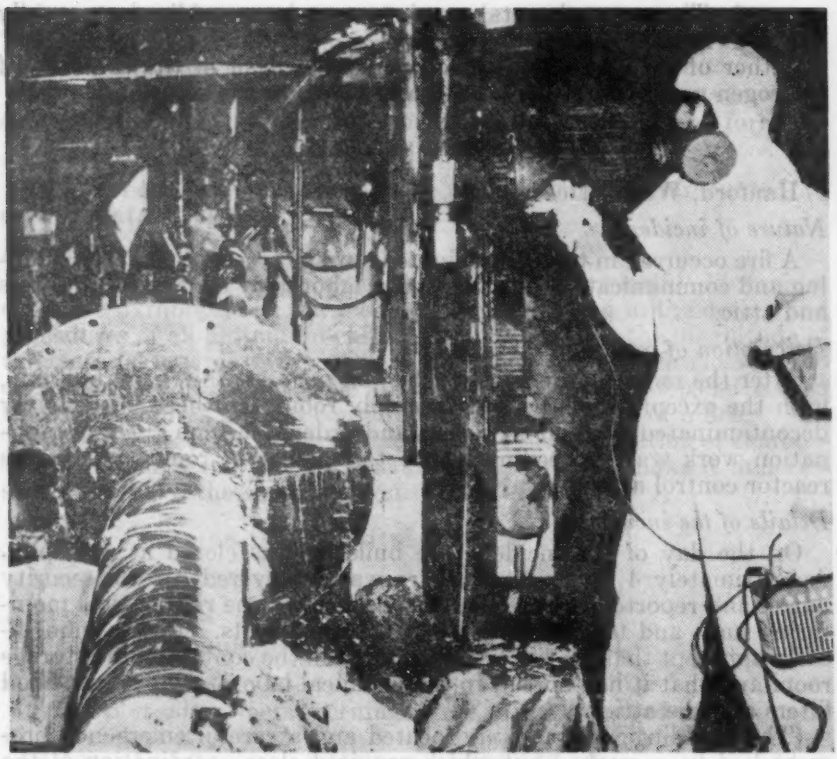
On the day of the incident the building was closed at 5:15 p.m. Approximately 4 hours later, a fire was discovered by the security patrol and reported to the emergency officer of the radiological monitoring unit, and the supervisor of the experiments. It was immediately apparent that the fire had originated in the contaminated storage room and that it had spread to the chemical laboratory exhaust hood filters and the attic.

(This building was remotely located and a careful emergency program had been worked out which required close coordination of the fire department and the radiation monitoring group for this and other buildings on the site containing operations with radioactive materials.)

Oxygen masks and other protective equipment were required due to the plutonium hazards. Qualified radiological monitoring personnel were present and took necessary measures to insure that procedures devised for fighting fires involving plutonium were followed and that all personnel and equipment were thoroughly surveyed and decontaminated prior to release from the area.

Considerable difficulty was experienced in extinguishing the blaze in the hood filters. It was necessary to break open the filter unit and remove the filter elements to put out the flames and prevent further release of plutonium to the atmosphere.

The total amount of plutonium released was estimated to be between 1 and 4 grams. Most of this came from the burned hood filter and the remainder from the previously contaminated waste material. All surveyable surfaces inside the building gave positive alpha readings. A part of the released plutonium was washed from the building by the water used to extinguish the fire, and deposited on the ground outside the building. The contaminated ground was covered with sand to prevent the pickup of active particles from the ground by winds.



Fire damage in contaminated waste fire.

Nature of injuries or loss

There were no injuries. Several firemen and one patrolman were found to be slightly contaminated. Decontamination was effected by washing with soap and water. Urinalysis samples were taken of all personnel working within the roped-off firefighting area.

Fire damage had obliterated the cause of the fire. It was the opinion of members of the damage investigating group that the fire originated by spontaneous ignition in the contaminated waste boxed in cardboard cartons in the contaminated waste room. Large quantities of contaminated waste in the form of paper, nitric-acid laden glass wool, rags, and miscellaneous material known to be contaminated were packaged in this manner prior to accumulation of sufficient number of boxes to require burial. The exact number of boxes stored in this room is unknown but there were at least seven. No waste cartons were added to this accumulation during the 30 hours preceding the fire. During this period, several boxes were rearranged to obtain access to an electrical outlet.

Remarks

It should be noted that the building involved in this and the previous incident was built for the purpose of conducting critical mass experiments and thus was remotely located and of minimum value. It was, therefore, economically feasible to abandon use of the structure after the radiation burst and the later fire.

Experimental work which might release a high degree of contamination should be carried out at locations which can be abandoned, or in facilities carefully designed to cope with the decontamination problem.

A further lesson to be drawn is that the accumulation of radioactive waste prior to disposal should not be done in violation of the elementary principles of good fire protection. Specifically, good housekeeping, segregation of materials liable to spontaneous ignition (e.g., nitric-acid-cellulose materials), and a storage location chosen with possible spread of waterborne or smokeborne contamination in mind, are indicated. An ordinary inconsequential rubbish fire can be quite costly if all the elements of risk are not properly evaluated.

FIRE IN DRY CONTAMINATED WASTE

Savannah River, December 14, 1954:

Nature of incident

Fire in cellulose waste which had been used with nitric acid to clean up contamination.

Description of operation

A metal mesh cage at the basement level was used for the storage of dry contaminated waste.

Details of incident

Fire was discovered in the cage. Personnel from the building were evacuated to another building because of the possibility of airborne radioactive material.

Smoke spread through portions of the building and an indeterminate area was contaminated. The fire department was summoned to combat the fire. Upon arrival they donned respiratory protective equipment and protective clothing. The fire was brought under control by use of water in approximately 15 minutes. All fire-fighting equipment was left at the scene of the fire for decontamination.

Surface contamination resulting from the fire was limited to the service floor and the elevator shaft which formed a flue for the rising smoke. Negligible airborne activity was detected on the main floor of the building. Normal operations were resumed on the following shift (day).

Nature of injuries or loss

Including damage to building and equipment, cost of labor for cleanup, and wages of laboratory employees evacuated from building—$665.

Remarks

The fire was the result of spontaneous combustion of nitric acid and cellulose materials (paper).

Preventive action taken:

1. All combustible contaminated waste is being stored outside buildings in metal dumpsters.

2. To eliminate time lost in assembling, equipping, and monitoring auxiliary firemen from the maintenance department before entering production buildings, employees in each major production building

will be trained as auxiliary firemen and used for fighting fires in that particular building.

3. Emergency fire and respiratory equipment will be located in each major building for use of auxiliary firemen.

RADIOACTIVE SODIUM FIRE

Knolls Atomic Power Laboratory, Schenectady, June 11, 1955:

Nature of incident

Fire involving radioactive sodium.

Description of operation

Some radioactive sodium was in a "hot" cell for chemical tests.

Details of incident

A leak developed in the apparatus and the sodium started to burn. The fire was extinguished with a special powder extinguishant which was sprayed into the cell. When the fire was discovered, the ventilation system was shut down and all personnel not essential to the operation were evacuated from the building.

Nature of injuries or loss

No one was injured and exposure was slight. Only one person received more than one roentgen.

Remarks

The possibility of such an incident had been anticipated and plans made accordingly. When this situation occurred, it was handled with a minimum of trouble.

Explosions

NITRIC ACID REACTION IN EVAPORATOR

Savannah River Plant, January 12, 1953:

Nature of incident

Chemical explosion involving radioactive materials.

Description of operation

Chemical evaporator involving radioactive material dissolved in nitric acid.

Details of incident

Explosion occurred during evaporation apparently from organic contamination.

Nature of injury or losses

There was severe physical damage but no personal injury.

Remarks

Recommendations bearing on the radiation hazards were as follows:

1. Health Physics should be called immediately if radioactive contamination is spread outside of a regulated area.

2. If noxious fumes or radioactive contamination are a possible result of an emergency in an area, a depot of protective clothing, gas masks, and other supplies should be established at a safe distance.

3. Areas covered by 2, above, should be so designated to the Fire and Patrol Departments and these groups should not approach closer than a predesignated distance without the express permission of the operating supervision.

PRESSURE RUPTURE OF DRUMS CONTAINING RADIOACTIVE WASTES

Knolls Atomic Power Laboratory, Schenectady, February 15, 1953:

Nature of incident

Rupture of drums containing radioactive waste.

Description of operation

An AEC contractor had for some time concentrated medium and low level radioactive wastes in a vacuum evaporator. Since it was known that the normally acidic waste materials of this type generated gases, provision was made in the standard operating procedure for treating the concentrated (60 to 65 percent solids) evaporator slurry to render it alkaline (i.e., pH greater than 7) prior to placing the slurry in sealed stainless steel drums for storage.

Details of incident

Operators entering the building containing the drummed waste noticed an unusual odor. Investigation revealed that one drum had "completely ruptured" causing widespread contamination; "slurry was spread over the surrounding area for a distance of 10 to 20 feet and splattered in other parts of the building for a distance of 30 to 40 feet." Following the rupture "the drum was blown up against the ceiling, * * *" causing, among other things, contamination of an overhead crane. The bulging heads on two other drums indicated that excessive internal pressure was present. To relieve the pressure, these drums were intentionally punctured from a distance of about 35 feet.

Nature of injury or losses

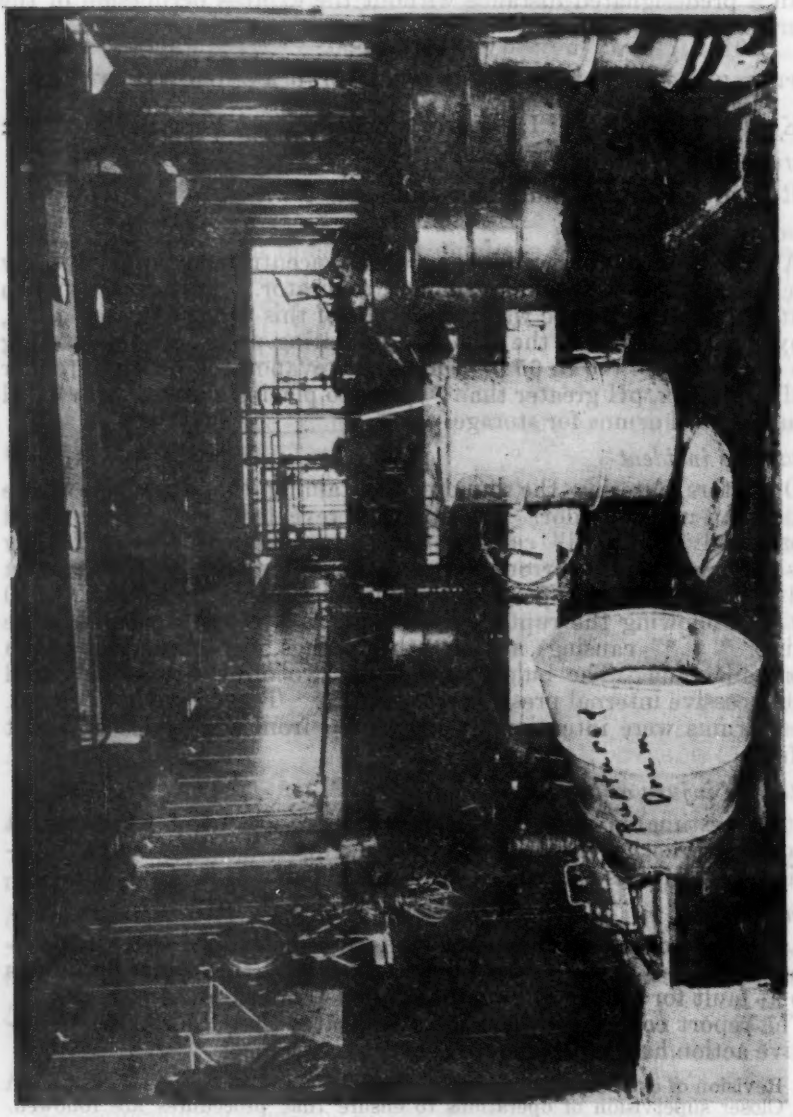
It was estimated that "the cleanup will require 4 to 5 weeks and it is doubtful whether it will be possible to reduce the degree of contamination to the levels existing before the incident."

Remarks

As a result of this incident, the contractor concluded that the operators had failed to check the slurry acidity and that supervision was also at fault for having allowed use of nonstandard procedures.

The report covering this incident indicates that the following corrective action has been taken to prevent recurrence:

1. Revision of existing operating procedures.
2. Closer supervision of operations to ensure that procedures are followed.
3. The pH of the evaporators must not go below 7 at any time during their operation.



Ruptured drum.

4. To prevent any change of acidity during the operation, all evaporator feed tanks will be checked once a shift and will be maintained at a pH greater than 7, which in itself precludes the possibility of the evaporator becoming acidic.
5. Approval for drumming must be given by the engineer in charge and must be based on a laboratory analysis.
6. The Chemistry Section has been requested to study the nature of the reaction which generates gases in acidic slurries.

MISCELLANEOUS

HIGH GAMMA DOSE TO HAND

Los Alamos, N. Mex., February 1949:

Nature of incident

Radiation overexposure to the hand from grasping "hot" end of gamma source holder.

Description of operation

A source holder with a 200 millicurie radium source was kept outside the laboratory building leaning against the building with one end on the ground. The holder was a piece of aluminum tubing 5 feet long and half-inch in diameter with a wire running inside the rod from a trigger at one end to a movable jaw at the other.

Details of incident

The usual practice of setting down the source holder was to put the hot end on the ground and the handle end against the building. On the day the incident occurred, there was snow on the ground, so when the source holder was placed outside the door, the usual position was reversed.

A short time later, the employee reached out the door and grasped the holder in the customary way, forgetting it was upside down. Several moments passed before he realized that he had hold of the hot end as there was very little to distinguish one end from the other.

Nature of injury or loss

There was no injury, although it was estimated that the gamma dose to the hand was about 40 r.

Remarks

The source holder was provided with a handle similar to a file handle over the cold end and the hot end was painted a distinctive color. A description of the incident was widely circulated among all employees using a similar tool.

BETA-RAY BURNS ON HANDS

Operation Sandstone, May 1948:

Nature of incident

Beta-ray burns of the skin of the hands of four individuals resulting from improper handling of fission samples.

Description of operation

During an overseas operation in the spring of 1948, drone aircraft equipped with air filters were used to secure samples of the cloud resulting from the experimental detonation of nuclear devices. The drone planes were landed at the Eniwetok airstrip, the air filters

removed from the planes, and the contained filter papers removed and packed in lead shields for immediate shipment by air for radio chemical study. The individuals who recovered the samples also acted as couriers in the return of the samples, and as there were short-lived activities of interest, the return flight took off immediately after the samples had been packaged and loaded.

Details of incident

Injuries occurred following two separate detonations. During the procedures associated with an earlier detonation, tongs 2 feet in length had been used for handling the filter paper samples, but difficulties were experienced due to the wind. In the subsequent two experiments, the use of tongs was abandoned and the filter papers were handled with the hands protected by thin cotton gloves over rubber surgeon's gloves. In one operation, an individual used gloves for only a part of the procedure, and discarded them after they became contaminated. A monitor apparently made no objection to these departures from the established procedure for the operation. It is impossible to make any firm estimate of the radiation doses involved to the skin of the hands, although the body gamma doses as estimated by film badges and radiation meters which the individuals wore were 1.7 r, 4.5 r, 5.5 r, and 17.0 r.

Nature of injuries or loss

Four individuals received beta-ray burns of the skin of the hands, of varying severity. On one man, the burn did not manifest itself until about 10 days had elapsed. The burn involved the thumb, index, middle, and ring fingers of the left hand. The lesion reached its maximum development in about 3 weeks and then began to subside. The other three individuals who received considerably greater exposure developed signs of injury much more promptly, noting pain and swelling within a few hours while on their homeward journey. Details of the management and clinical progress in the four cases were published in 1949.[11]

One individual has no residual disability except for minimal changes in the skin of the left hand believed to be due to his radiation exposure. The other three individuals have had skin grafts of the hands. One individual has had some small areas of skin grafted as recently as June of 1955. This man has considerable disability of both hands consisting of flexion contractures, ankylosis of joints of the fingers, and subcutaneous tissue atrophy. One has similar changes but less severe. Another has essentially no residual functional disability, but does have extensive grafted areas on the hands.

Remarks

The injuries arose primarily from the failure of the monitor and the individuals concerned to recognize the potential danger from beta radiation. In the original design of the experiment, sufficient distance had been provided so that the contribution of beta radiation to dosage would be negligible.

To prevent a recurrence of such injuries the experiment has been completely redesigned. Changes have been made in the filter holder and associated equipment designed to permit completely remote handling and packaging of such samples in all subsequent tests.

[11] Knowlton et al.: Journal of the American Medical Association, 141, pp. 239-246 (Sept. 24, 1949).

RADIATION MACHINERY INCIDENTS [12]

Nature of incident

Two cases of persons being irradiated by a linear accelerator.

Description of operations

The incidents occurred at a university linear accelerator being operated for research purposes.

Details of incident

Case I.—Two graduate students, who were employed as research assistants were at work in a room closer to the target end of the machine than to the control panel. They had installed the target in the machine and were engaged in observing the recording of particular counts as reported in the counting equipment in the room. On two occasions they decided that the target was not properly installed and went from the room to the end of the machine to adjust the target. The first time both persons followed proper procedure in that they notified the accelerator operator by phone before leaving the room that they were going to the machine to adjust the target, and they also removed from the rack the high voltage interlock key, the absence of which from the lock makes it impossible to turn on the accelerator beam. They adjusted the target, returned to the room, replaced the interlock key, and informed the accelerator operator that all was well again.

After some time, they concluded that the target was not yet properly alined and they left the room to adjust it. This time they failed to inform the operator of their intention, did not remove the interlock key, ignored warning lights and signs, and the sound of the accelerator klystron pulsers. They went into the target area, pushing aside a number of heavy coaxial cables which were in their way. One experimenter leaned over, adjusted the target by hand, and then bent over still more to make the alinement by eye. When he did so, he noticed a bluish irridescence in his eyeglasses. The other experimenter stood right behind him. Upon seeing the flash, the first immediately stood up. Both realized what had happened, and both left immediately and informed the operator of what had happened.

The incident was immediately reported and a physician called in. A series of measurements and calculations were made to determine the probable exposure. The subject was studied intensively by the physician for several weeks. No signs of damage were found. After 3 weeks, the physician permitted him to return to the laboratory and he has continued service since then.

An unusual situation existed at the time of the accident which made it possible. An extension of the building was being constructed at the target end of the accelerator. Temporarily, a partition existed between the two sections and, as a result, the target end was not completely barricaded. On the other hand, both of the experimenters were experienced graduate students, well aware of the hazards and of proper safety precautions. The one who was exposed in particular had spent more than a year as a full-time accelerator operator, and it has been a part of his job as such to concern himself with the safety of persons in the building during operation. In addition, the re-

[12] NOTE.—These incidents did not occur at an AEC site but are included because they represent the radiation hazard which is present with these machines.

quirement that experimenters work in tandem was made primarily to assure that safety precautions would be observed.

After this incident, operations were suspended until the target area had been enclosed.

Case II.—The second exposure involved an inexperienced part-time worker, whose job it was to fill vacuum pump traps with liquid nitrogen on Saturday and Sunday afternoons. Three circumstances contributed to this exposure. First, the man had not been adequately indoctrinated and hence did not pay attention to warning devices or signs. Second, it was possible for him to enter the halfway station acrobatically from the top of the accelerator shielding instead of through the interlock gates at front and back end, and he did so in order to save time. Third, an unwarranted assumption was made by the accelerator operator that this person was no longer in the halfway station, and so the accelerator beam was turned on while he was still in.

The trap filler had told the operator that he was about to fill traps in the halfway station and the accelerator was put out of operation. The person was subsequently seen by an experimenter on the other side of the accelerator in a safe area, and the experimenter concluded that the halfway station traps had been filled. However, the trap filler was merely getting more liquid nitrogen to use, and he twice returned to the halfway station. Meanwhile, the operator was warming up the machine and putting it into operation.

In the experiment going on at the time, the electron beam was diverted from the accelerator into a magnet spectrometer in the station. After emerging from the spectrometer, the beam came out into the air in a direct line to intercept the trap filler at one of the traps. It was estimated that the trap filler was in this position for approximately one-half to 1 minute, and in the general area, but in a less exposed position, for another minute or so. The effect of the direct-line exposure to the beam would undoubtedly have been more serious had it not been for a very fortunate circumstance, namely, that on that particular day a television camera had been installed on a homemade wood mount to monitor the beam as it came out of the spectrometer. The wood mount was located between the spectrometer and the trap in such a position as to stop the beam in some measure, but chiefly to spread it.

The subject was intensely studied by the clinic and no signs of any damage were found. He is presently at work for the laboratory but in a job which does not involve any exposure to radiation.

Following this incident, conditions were studied quite thoroughly and various measures taken. The halfway station was the only point at which acrobatic entry could be made to an area in which the electron beam emerges into air. The problem of providing a permanent roof for the station poses major structural problems which have not yet been solved, but a frame and wire top has been installed, operating procedures and discipline have been tightened, and a system for more adequate indoctrination of all laboratory personnel was initiated.

NITROGEN ASPHYXIATION

Knolls Atomic Power Laboratory, March 18, 1951:

Nature of incident

An employee was asphyxiated when he used an air-line mask which was accidentally supplied with nitrogen.

Description of operation

Employees entering an area where there was a serious hazard with respect to inhalation of radioactive materials were required to use air line masks. The air line was also used to provide instrument air. A regular compressor and a standby compressor were provided on the air line.

Details of incident

Over the weekend, both compressors were out of service, so bottled nitrogen was manifolded into the line to maintain instrument air pressure. An employee working alone entered a radiation-hazard area and was found dead due to asphyxiation because of the nitrogen substitution in the air line.

Nature of injuries or loss

One fatality.

Remarks

No radiation was involved in this incident; the fatality was due indirectly to the fact that the area was one in which the precautions against exposure to radioactive materials made it necessary to use the air line.

The closest control must be maintained over all operations involving the use of supplied air or self-contained masks. Basic rules should include:

1. No employee should enter an area requiring such equipment unless tended from outside.
2. Breathing-air systems should be used for this purpose only.
3. Air-line respirators should include a self-rescue air cylinder.
4. Employees should be instructed in the difference between acute and chronic radiation hazard.
5. Where such equipment is used in a situation where the life hazard is not acute, employees should be instructed to remove the mask and leave the area if trouble develops with the mask.

34434—59——20

Chalk marks show position of body when found.

UF_6 LEAKS

Nature of incidents

A number of leaks of UF_6 (uranium hexafluoride) have occurred due to mechanical failures of equipment.

Description of operations

UF_6 is the gas used in the isotopic separation of U^{235} and U^{238}. It is handled through miles of piping and thousands of pumps and similar equipment.

Details of incidents

From time to time leaks occur from the same causes as occur in any chemical plant.

Nature of injuries or loss

The radiation hazard is unimportant. UF_6 reacts with H_2O in the air to form HF, thus personnel exposed may receive HF burns. In heavy concentrations, the UF_6 may react directly with body tissues.

Remarks

Leak prevention control procedures parallel those for HF.

INADVERTENT EXPOSURE AT TEST

Nevada Test Site, March 1, 1955.

Nature of incident

An overexposure of radiation was received by a security guard.

Description of operation

The security guard was to accompany the radiation safety monitors into the exclusion area after a weapons test and establish surveillance of equipment. The guard had his own vehicle.

Details of incident

When he arrived at the place where he was to meet the monitors, the guard found that they had already left and started out after them. Somehow he lost his way and drove beyond the safety point that had been set up. When it became apparent that he could not find the radiation safety monitors, he contacted his headquarters, by radio, and notified them of his position. He was immediately ordered out of the area.

Nature of injury or loss

The guard's film badge indicated he had received a dose of 39 r. However, continuing blood analyses and physical examination indicate no radiation symptoms.

Remarks

The radiation safety plan has been revised to prevent a recurrence of this incident.

RADIATION EXPOSURE

Hanford, May 11, 1953:

Nature of incident

Inadvertent handling of irradiated solid aluminum pieces.

Description of operation

Three irradiated solid aluminum pieces were washed out of the front face end of a process tube on the 105–DR reactor. Two nearby employees, thinking that these aluminum pieces were "cold" pieces that they were in the process of charging, each picked up one of the irradiated pieces. One of these employees handed his piece to another employee who was to "charge" it before it was realized that these pieces were probably irradiated.

Nature of injuries or loss

Eleven people were nearby at the time of the incident, though it is believed that only six of them received exposure in excess of the permissible limit. Of these six, only three (those who had handled pieces) were believed to have received significant overexposure. Each was estimated to have received a hand dose of 100 r. The beta hand dose was estimated to range for the three employees from a possible minimum of 30 rad to a maximum of 330 rad. The maximum "whole body" dose was estimated to about 3.5 rad including 2 r.

Remarks

More adequate communications were established between the charge face and discharge face of the reactor to prevent one group from opening a tube while the other end of the tube was still under high water pressure.

More adequate prejob planning measures were inaugurated.

NOTE.—It was not realized prior to the incident that lightweight (aluminum) pieces were upstream from the main charge. Also it was not known that the comparatively low water pressure that was on the tube could wash out such aluminum pieces under the conditions planned.

RADIATION BURN

Los Alamos, September 1948:

Nature of incident

Employee received radiation burn.

Description of operation

Employee was unpacking radioactive material.

Details of incident

While unpacking material he allowed it to rest against his leg.

Nature of injuries or loss

The man received a radiation burn on his ankle. He lost 36 days from work. Compensation was paid. He made a full recovery.

JANUARY–DECEMBER 1956

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

(*a*) Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

(*b*) Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission to the extent that such employee or contractor prepares, handles or distributes, or provides access to, any information pursuant to his employment or contract with the Commission.

This report has been reproduced directly from the best available copy.

PREFACE

This publication is intended to summarize the incidents involving radioactive materials which occurred in atomic energy activities during 1956. It supplements TID–5360, "A Summary of Accidents and Incidents Involving Radiation In Atomic Energy Activities—June 1945 Through December 1955."

COBALT–60 EXPOSURE

Milford, Conn., January 10, 1956.

Nature of incident

Workman picked up an encapsulated 1,600 mc. cobalt–60 source.

Description of operation

A cobalt-60 source, attached to a string and suspended to a floor below, was being used on a construction job to radiograph welds.

Details of incident

An employee of the construction contractor removed the cobalt–60 capsule from the string and put the capsule into his shirt pocket, removing it several minutes later to the glove compartment of his automobile.

Nature of injuries or loss

The employee received an estimated whole body gamma dose of 22 to 26 rads and an estimated dose to two small skin areas of about 3,600 r each. There were no latent effects and no blood changes were detected. Three others in his car pool were exposed to estimated doses of less than 7 r.

SLIGHT CONTAMINATION OF CONSTRUCTION AREA

Oak Ridge National Laboratory, January 16, 1956.

Nature of incident

The work area of a construction company was slightly contaminated as a result of nearby laboratory operations.

Details of incident

A construction area was slightly contaminated when radioactive dust was ejected from a nearby laboratory. As a routine precautionary

measure, articles of clothing, such as caps, gloves, coats, and shoes, were removed from the 26 employees in the area for cleaning.

Nature of injuries or loss

No one was exposed to more than a small fraction of the maximum permissible daily dose. No ill effects resulted.

PLUTONIUM CONTAMINATION TO HANDS

Hanford, Wash., January 17, 1956.

Nature of incident

Plutonium contamination to employee's hands.

Description of operation

Manual handling of radioactive material.

Details of incident

Operator was doing routine work when a plutonium bearing organic solution caused deterioration of his rubber gloves.

Most of the initial skin contamination (about 100 milligrams of plutonium) was removed by washing, although it required a period of 50 days to remove the remaining 200 micrograms of radioactive material.

Nature of injuries or loss

Bioassay results obtained several months after the incident indicated that the internal deposition of soluble plutonium did not exceed 5 percent of the maximum permissible body burden.

Remarks

The main objective of the decontamination procedures was to minimize absorption through the skin.

EXPOSURE INCIDENT

Las Vegas, Nev., January 18, 1956.

Nature of incident

Four employees were exposed to radiation.

Description of operation

The employees were recovering samples from a nuclear test area in Nevada.

Details of incident

After the prescribed time which was set up before the test, four men, dressed in proper protective clothing, entered the hazardous area to recover samples. It had been prearranged to have a monitor enter the area in advance of the men; however, they entered the area without the monitor to redeem the samples.

Nature of injuries or loss

The four employees received external radiation exposures of 4r, 14r, 19r, and 28r, respectively (the recommended permissible level at the time was 3.9r/13 weeks). After examination, the men showed no signs of ill effects.

CRITICALITY INCIDENT

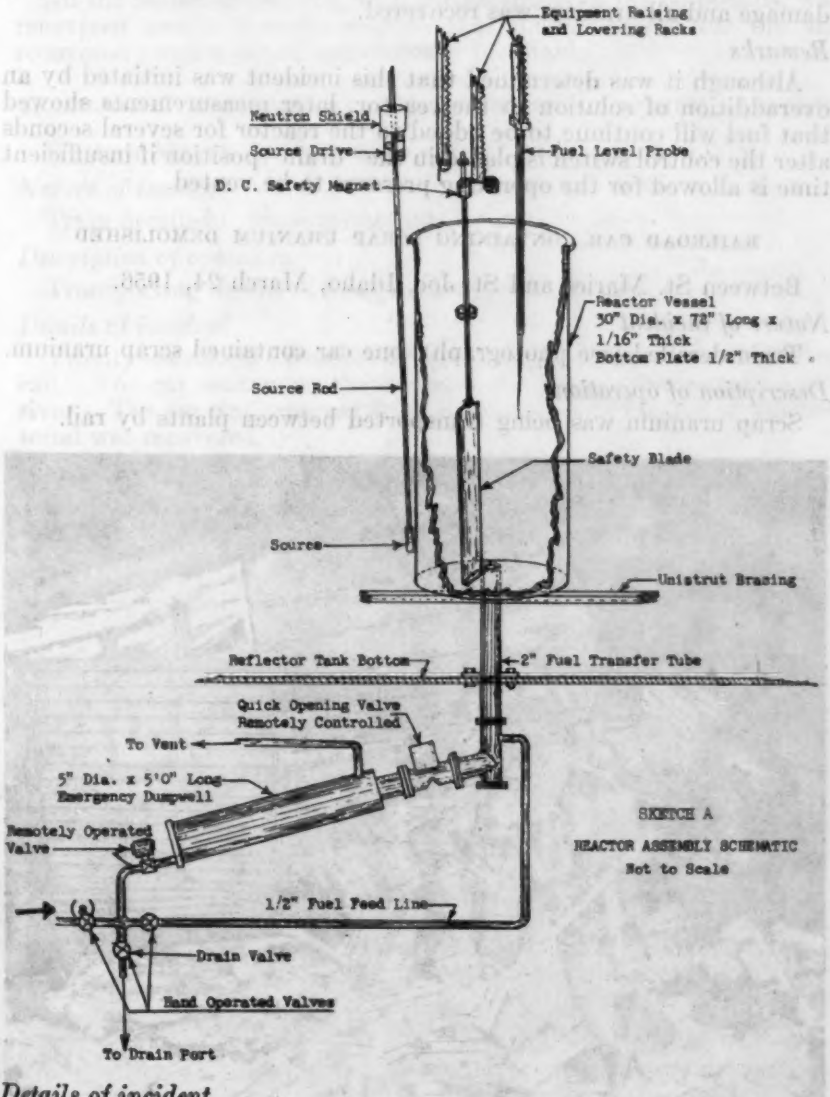
Oak Ridge National Laboratory, February 1, 1956.

Nature of incident

Neutron and gamma ray exposure.

Description of operation

Criticality experiment with experimental reactor.



Details of incident

A homogeneous UO_2F_2 water moderated critical assembly was put on a prompt critical period by an overaddition of fuel to the assembly. Before reaching the critical point, the hand-operated valve (see sketch

A—(a)) was turned off. However, fuel continued to be added to the reactor due to air pressure in the line. Although the automatic safety system operated, assuring termination of the burst, considerable fuel was displaced from the reactor. The number of fissions in the burst was estimated to be about 1.6×10^{17}.

Nature of injuries or loss

No serious exposures resulted since all personnel were shielded by a minimum of 5 feet of concrete. There was no significant property damage and all uranium was recovered.

Remarks

Although it was determined that this incident was initiated by an overaddition of solution to the reactor, later measurements showed that fuel will continue to be added to the reactor for several seconds after the control switch is placed in the "drain" position if insufficient time is allowed for the operating pressure to be vented.

RAILROAD CAR CONTAINING SCRAP URANIUM DEMOLISHED

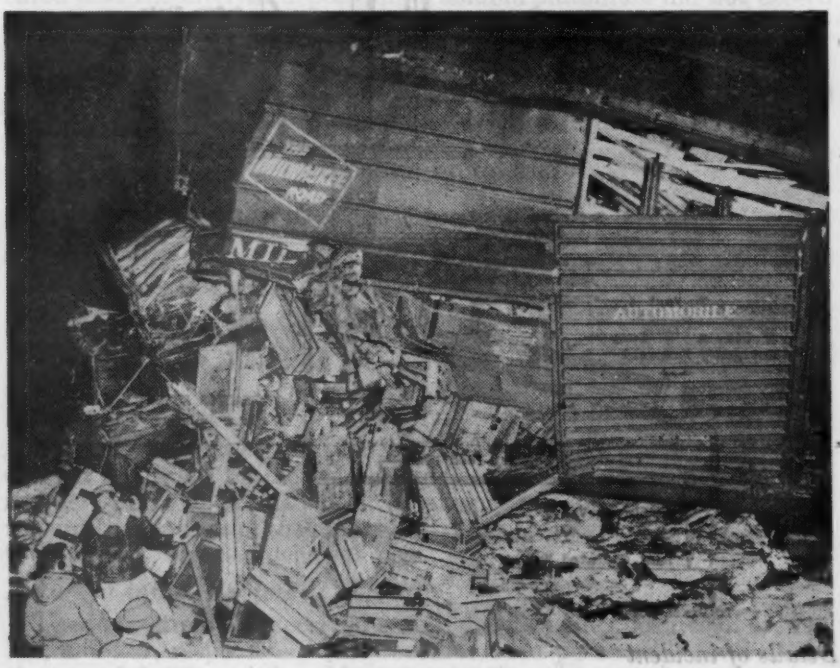
Between St. Maries and St. Joe, Idaho, March 24, 1956.

Nature of incident

Train derailed (see photograph); one car contained scrap uranium.

Description of operation

Scrap uranium was being transported between plants by rail.



Details of incident

A train which contained a carload of scrap uranium was derailed by a rock and snowslide. The car containing the scrap uranium was

demolished and the contents spilled on to the right-of-way. Radiation detection instruments were used in locating the material.

Nature of injuries or loss

Loss involved 60 pounds of uranium scrap believed to be buried under the earth and rock. There was no radiation exposure to personnel.

Remarks

All the material involved, with the exception of the 60 pounds, was recovered and it was determined that further search for the unrecovered scrap was not economically justifiable.

DERAILMENT OF FREIGHT CAR TRANSPORTING A URANIUM COMPOUND

Western Mont., April 20, 1956.

Nature of incident

Train derailed. (See photograph.)

Description of operation

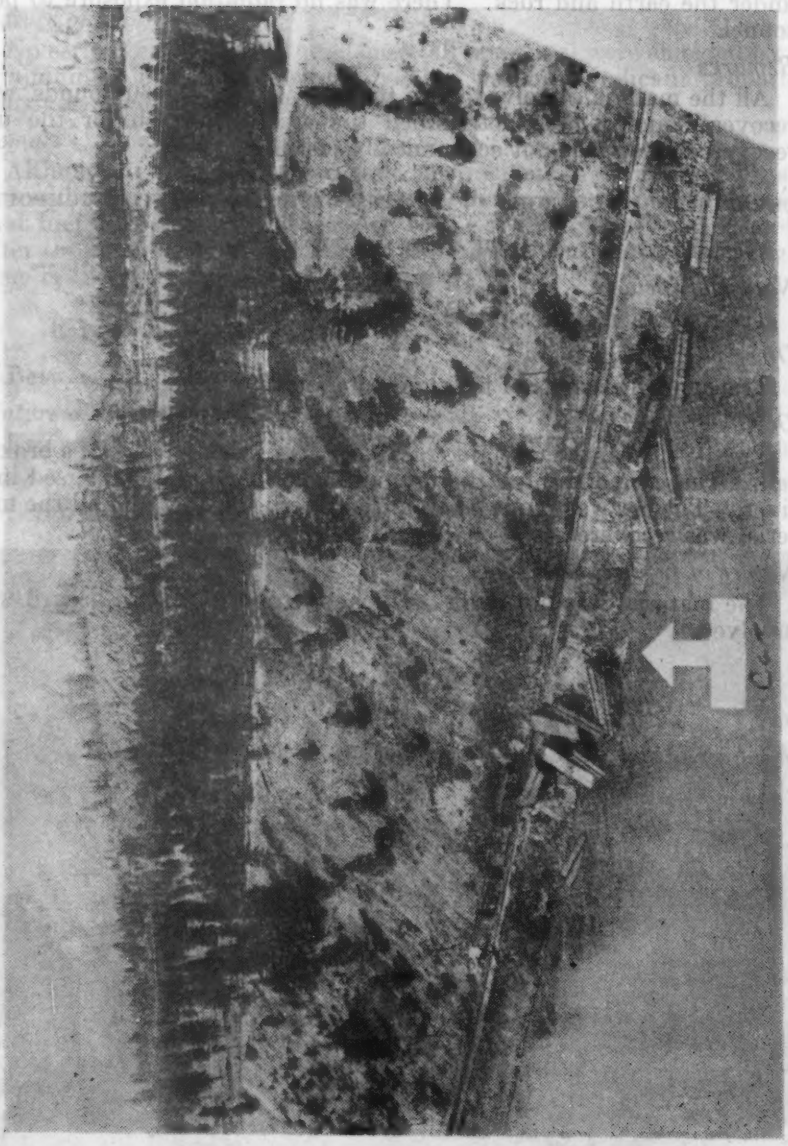
Transporting drums of uranium compound by rail.

Details of incident

Twenty-six cars of a freight train were derailed as a result of a broken rail. The car containing the uranium compound was immersed in a river. The car was removed from the riverbed intact and all the material was recovered.

Nature of injuries or loss

The material was not highly radioactive and no health hazard was involved.



BETA RADIATION BURN

Los Alamos Scientific Laboratory, April 30, 1956.

Nature of incident

Beta radiation injury to employee.

Description of operation

During a routine radiochemistry procedure, a tool used for preparing neutron sources was removed from a hot cell to be decontaminated.

Details of incident

The tool was removed from the hot cell into the radiation room by the use of a long pole. Then it was put into a bucket (by hand) and taken to the sink for decontamination. During the decontamination process, the employee noticed that his pocket dosimeter was off scale. He immediately went to the monitoring station for a check. It was ascertained that rubber gloves were worn during the entire operation; the manner of contamination therefore could not be determined.

Nature of injuries or loss

The injured was hospitalized 14 days, for skin grafting to the middle finger, left hand, as a result of a beta burn received apparently when the tool was placed in the bucket by hand.

GAMMA EXPOSURE INCIDENT

Fort Belvoir, Va., May 14, 1956.

Nature of incident

Fifteen to twenty-five employees were exposed to gamma rays.

Description of operation

Radioactive iridium 192 was being used for field X-raying welds.

Details of incident

While working near a portable radiographic source, the employees were exposed to small doses of gamma radiation when a cap was knocked off a pig containing a 32-curie iridium source. The cap was set lightly on top of the pig with a string coming out of the pig. The string became entangled some time during the day and was pulled out of the pig, knocking off the cap and exposing the source. The men working on and around the scaffold, on which the pig had been placed, were exposed.

Nature of injuries or loss

The maximum amount (6 r) of radiation which could have been received by these employees would not be enough to cause any illness. No abnormalities were indicated by results of laboratory examinations. They returned to work the following day.

Remarks

This incident is attributed directly to the fact that the employee failed to store the source in accordance with outlined procedure.

EXPOSURE TO PLUTONIUM

Hanford, Wash., June 18, 1956.

Nature of incident

Several employees received significant body burden of plutonium.

Description of operation

The men were doing semiroutine work in a chemical plant control room.

Details of incident

Some highly concentrated plutonium solution backed up in the instrument line of an air-operated valve and about a pint escaped into the control room. Personnel in the area were exposed to airborne plutonium.

Nature of injuries or loss

One employee was hospitalized 4 days for observation, decontamination, and special treatment; a second and third were given treatment at the hospital (no lost time) in connection with inhaled plutonium.

An estimated cost of $5,000 was incurred for decontamination of the plant.

Remarks

The committee investigating the incident made the following recommendations:

1. The plant should review existing process equipment where pipe-type connections are present between process cells and operating area.
2. Action should be taken immediately to eliminate obvious potential hazard of the type which caused this incident and on a long-range basis to reduce generally the potential for process solution blow-backs.
3. All building safety rules should be reviewed and revised as necessary to specify the minimum requirements for protective personal clothing to be worn while working in chemical plant area.

CONTAMINATION INCIDENT

Los Alamos, N. Mex., June 21, 1956.

Nature of incident

Contaminated blotting paper blew around the room during an experiment.

Description of operation

Experiment involved highly radioactive material.

Details of incident

During the course of the experiment, the piece of blotting paper, which had become contaminated with radioactive material, blew around the room for some unexplained reason, causing contamination of the area. There was a possibility that all of the occupants of the room were exposed.

Nature of injuries or loss

Eight employees were exposed within the permissible limits; two received maximum permissible exposure. No one required hospitalization or treatment.

No dollar loss due to contamination was involved.

JACKET FAILS ON SOURCE

Eniwetok Proving Ground, June 23, 1956.

Nature of incident

Plutonium oxides were released from a plutonium alloy instrumentation source.

Description of operation

Plutonium instrumentation source stored in trailer.

Details of incident

Plutonium oxides were released when the jacket failed on the source stored in a house-type trailer. The failure of the jacket caused contamination to about 15 persons and their living quarters, including clothing and bedding. Decontamination was carried out according to standard procedure and items too heavily contaminated to be made usable were buried at sea.

Nature of injuries or loss

Bioassays were made on all personnel exposed and it was found that all body burdens were negligible and well below permissible amounts.

THORIUM EXPLOSION

Bayside, N.Y., July 2, 1956.

Nature of incident

A thorium explosion occurred in a metallurgy laboratory which resulted in injury to nine employees.

Description of operation

Burning of thorium metal for conversion to oxide in a hood. (This conversion is standard procedure for handling uranium and thorium scraps to reduce fire potential during subsequent shipment.)

Details of incident

One of the employees in the laboratory (wearing personal protective equipment) took a piece of thorium metal about the size of a golf ball from a drum which contained 30 to 40 pounds of the material and put it onto a tray, located inside the ventilated burning hood, by means of a pair of tongs. (Some of the metal in the form of wafers had already been fired in the tray to act as a source of ignition for the new material.) There was an immediate sharp explosion, followed almost immediately by a second blast.

Nature of injury

Nine persons received injuries as a result of the explosion; four of these were hospitalized because of burns and other injuries, and one died about 5 weeks later. Except for four laboratory workers, the analyses of urine specimens from all persons associated with the

incident (firemen, policemen, etc.) showed no detectable intake of radioactive materials. The four men directly involved did not exceed the permissible body burden for uranium or thorium.

Measurements were made both inside and outside the building during the first 4 hours after the explosion for alpha surface contamination and for direct radiation from beta and gamma; no significant radiation was evident. Property damage was estimated at approximately $125,000.

INTERPLANT SHIPMENT ACCIDENT

Monterey, Tenn., July 9, 1956.

Nature of incident

Trailer-truck overturned and caught fire.

Description of operation

Transportation of slightly radioactive material.

Details of incident

The braking system reportedly failed on a downgrade and the driver lost control of the unit as he attempted to negotiate an "S" curve. The vehicle skidded across the highway into a soft ditch, plowed up the shoulder for approximately 100 feet, then up an embankment on the left side of the road, overturned, and burned (see photographs).

Nature of injuries or loss

The driver was hospitalized for burns and bruises resulting from the accident. There was no loss of material.

WORKMEN EXPOSED TO RADIATION ON A REACTOR

Materials Testing Reactor, Idaho Falls, July 23, 1956.

Nature of incident

Eight men received radiation exposures from large gamma source.

Description of operation

The Materials Testing Reactor was shut down for scheduled refueling and experiment installation operations.

Details of incident

Six employees were working on the reactor top adjacent to the reactor tank opening; two men were present as observers and advisers. The exposure occurred when a highly radioactive reactor component was placed in a position where it was not adequately shielded because of lowered water level in the reactor tank. The moving of the component and the coincident lowering of the water level were both done to facilitate insertion and removal of experiments in the reactor.

Nature of injuries or loss

The eight employees received radiation exposures ranging from 2.5 r to 21.5 r, which was not sufficient to cause illness to any of the men, although they were placed under routine medical observation.

Remarks

Full-time radiation monitoring service will be provided at this location as soon as the necessary health physics personnel can be obtained.

DOCKSIDE TEST OPERATIONS RESULT IN SLIGHT EXPOSURE

Seawolf, August 19, 1956.

Nature of incident

Seven persons were exposed to radiation.

Description of operation

Dockside test operations on the *Seawolf*.

Details of incident

The men received minor radiation doses, the highest of which was 1.1 r. The exposure occurred during the testing procedure and was not the result of a malfunction of the nuclear reactor or of normal plant operations.

Nature of injuries or loss

No radioactivity was released to the air or water. No ill effects to the exposed personnel resulted, and no damage to the ship or equipment was involved.

PLUTONIUM CONTAMINATION INCIDENT

Hanford, Washington, September 21, 1956.

Nature of incident

Plutonium-bearing solution splashed on employee.

Description of operation

A container of plutonium-bearing solution was being prepared for shipment.

Details of incident

In filling the container, some of the solution rested in the recess at the mouth of the container in which the gasket sits. When the cover was applied, drops of the solution splashed out on to the employee's chest and face and into his mouth. Decontamination procedures were instituted and all accessible parts of his body were adequately cleaned.

Nature of injuries or loss

Emplovee was sent to the hospital (no lost time) for observation. The results of biological tests indicated that the amount of plutonium in his body was below the permissible body burden.

Remarks

No serious consequences are anticipated as a result of this incident.

SPONTANEOUS MASSIVE THORIUM FIRE

Detroit, Mich., September 22, 1956.

Nature of incident

A spontaneous fire occurred in a drum of thorium metal pellets en route to an AEC licensee.

Description of operation

Railroad shipment of thorium pellets.

Details of incident

The shipment arrived at the Railway Express Agency warehouse where it was loaded onto a truck for further transport. A few minutes after loading the truck, smoke was noted rising from the load. The source of smoke was found to be a drum which was pushed from the trailer and allowed to burn itself out. The fire lasted about 2½ hours.

Nature of injuries or loss

No one involved in the incident received any exposure of thorium or radiation in excess of maximum permissible amounts.

RADIOACTIVE SHIPMENT ACCIDENT

Pleasant Valley, Oreg., December 11, 1956.

Nature of incident

Semi-tractor-trailer truck loaded with two casks containing radioactive slugs went over an embankment.

Description of operation

The slugs were being transported between plants by tractor-trailer.

Details of incident

On a rainy morning (temperature 26°, resulting in a glazed road) a semitrailer was coming out of a downgrade "S" curve when the trailer started slipping toward the right on the outside of the curve. In the next 150 feet, the trailer went over the bank (see photograph)

and was dragged behind the tractor which was maintaining traction on the shoulder. The weight of the trailer (21 tons) was straining on the kingpin and fifth wheel and, as the trailer slipped further down the 25° slope, the fifth wheel tore loose from the tractor causing the tractor to flip over on its right side. The trailer started rolling down the embankment. The rear cask broke loose during the roll and stopped in an inverted position on a shelf about 30 feet below the road surface. The trailer continued rolling to an upright position where it stopped with the forward cask still secured to the bed although it had slipped to the left about 12 inches and flattened the stainless pan side.

Nature of injuries or loss

Neither the driver nor the relief driver was seriously injured; the latter was sent to the hospital for observation.

An instrument survey was made of the equipment, area, and personnel. All slugs remained safely in the casks.

PLUTONIUM CONTAMINATION INCIDENT

Hanford, Wash., (date not given).

Nature of incident

Contamination by plutonium carried by flushing solution.

Description of operation

Cleaning of a plutonium concentrator cell line by means of steam pressure.

Details of incident

The plant had been shut down to clear a plugged line in the plutonium concentrator cell. In the course of the work, inadequate venting resulted in the system being pressurized with air. Plutonium-containing flushing solution and mist were forced into the gallery from temporary instrumentation connected to the tank, contaminating about 300 feet of the gallery, and causing extensive skin and clothing contamination of a chief operator. A maintenance foreman also received hand and clothing contamination, but to a lesser extent.

Nature of injuries or loss

No employees were overexposed to radiation. The costs for plant decontamination and equipment replacement were $20,000 and $30,000.

Remarks

Clear step-by-step procedure should be written for all nonstandard operations and given formal status. The use of temporary manometers on plant process equipment should be rigidly limited and controlled.

TRITIUM EXPOSURE

(Location and date not given.)

Nature of incident

An employee was exposed to tritium.

Description of operation

Employee entered a ventilated area to make an equipment change.

Details of incident

When the employee opened the shielding door to the extraction furnace, the plastic bag pulled off the ring and, due to the lower pressure, was drawn into the space between the furnace and the shielding wall. Instinctively, the employee attempted to grab the bag but failed, so he inserted one hand and arm up to his shoulder into the port to retrieve the bag. He did not know whether he had handled the clean or contaminated side. After fastening the bag in place, the employee removed his gloves and did not wash his hands. Approximately 30 minutes later he went for a smear count which indicated that he had received more contamination than the permissible limit. He was instructed to immediately take a shower.

Nature of injuries or loss

The employee did not suffer any injury nor was he hospitalized.

Remarks

Although the cause of this incident cannot be determined, it has pointed out the need for additional control of access to areas of high potential hazards.

JANUARY THROUGH DECEMBER 1957

REACTOR ACCIDENT

Santa Susana, Calif., January 4, 1957.

Nature of accident

High level volatile activity was observed in a KEWB reactor building.

Description of operation

The contamination of the reactor test building occurred during a series of routine operating reactor tests which involved the use of the auxiliary apparatus.

Details of the accident

One person was exposed to high level volatile activity for approximately 10 seconds, receiving approximately seven times his daily breathing tolerance based on pessimistic assumptions for the calculation. An independent estimate showed the exposure to be less than one daily tolerance dose. A survey showed no particular contamination outside the reactor test building. Some low level gaseous activity was detected in the electrical building, which is located immediately above the test building. Within 24 hours, the activity in all rooms of the test building was reduced to background by the use of the forced ventilation system provided for the building. The building was then entered and inspected; the leak appeared to be caused by the failure of a vacuum pump. The pump was replaced and the necessary decontamination was completed.

Nature of injuries or loss

The member of the KEWB staff exposed to the activity had entered the test building on schedule, 15 minutes after shutdown, to measure the core pressure. A radiation survey at the door indicated no unusual radioactivity in the valve gallery. As this was being done another staff member checked the remote continuous gas sampler and found it above breathing tolerance. The test building was vacated immediately after about 10 seconds of occupancy.

The employee's internal dose was less than 50 mr. No measurable (less than 1 mr) external whole body dose was received during the incident. No detectable activity above normal background was found by radiourinalysis during the ensuing 36 hours.

Remarks

The apparent cause of the contamination was the malfunction of equipment which had operated satisfactorily for a period of 7 months. This equipment was a part of the auxiliary plumbing system and was not an intregal part of the reactor system.

The activity levels resulting from the contamination were relatively minor and were easily removed. After the decay of the volatile

activity, the cleanup job might be compared to that required in the event of a radioactive spill in a radioisotope laboratory.

The KEWB test facility was shown to be properly equipped to handle contamination of a much greater magnitude than that described here.

GODIVA

Los Alamos, N. Mex., February 12, 1957.

Nature of accident

A fissionable material assembly, remotely operated, produced a neutron burst greater than intended, resulting in a rupture of the assembly.

Description of operation

A neutron-producing assembly, called Godiva because of its bare configuration, was to be used to irradiate uranium-loaded graphite samples. The samples were to be heated in a shielded furnace, exposed to a "prompt" burst of neutrons and then transferred to a counter for evaluation. The experiments are conducted at an isolated site in a building separated from the control room (and all personnel) by about a quarter of a mile. The mechanisms are operated remotely. Although excessive radiation, to the degree experienced in this accident, does not occur routinely it is not entirely unexpected.

The prompt burst is produced by bringing together different sections of U^{235} to form a sphere. The exact degree of criticality is determined by preset control or reactivity rods, also enriched with U^{235}. The assembling was expected to achieve a condition slightly above prompt critical, a condition which produces a burst of 10^{16} fissions or a total energy of about 100 watt-hours. The heat of the reaction expands the uranium and reduces the reactivity below prompt critical, thus terminating the burst, and then the parts are mechanically separated.

Details of accident

On the occasion of the accident, preliminary bursts were being produced. In the process of lowering the top safety block, the unexpected burst occurred, a burst that was estimated to have produced 1.2×10^{17} fissions or about 12 times the normal energy of a prompt burst and about twice the energy of a previous incident which occurred in 1954. The energy was great enough to tear the uranium parts from the assembly (knocking one to the floor), and distorting the steel rods in the frame. The uranium was deformed and there was much more surface oxidation than usual.

Nature of injuries or loss

There were no personal injuries or overexposures. As stated above, the operation was carried out remotely and no overexposures would be expected. No gamma radiation above background was detected outside the building. Radiation levels in the building were high initially—7 r. per hour gamma just inside the door (12 feet from Godiva) and 5,000 to 20,000 counts per minute (per 55 cm^2 probe) alpha on horizontal surfaces about the room—therefore cleanup procedures were delayed 2½ days until scrub-down could be completed without unnecessary exposure to cleanup personnel.

34434—59——22

Property damage

The total property loss was estimated at $2,400, distributed as follows:

Fissionable material, U^{235}	$200
Damage to frame and electronic equipment (too contaminated to clean)	2,000
Cleanup labor	200
Total	2,400

The building was placed back in operation 8 days later. Personnel were utilized in other activities in other facilities. One important experiment was carried on in this building during this period with the personnel wearing protective clothing.

Remarks

The burst was believed to have been caused by accidental movement toward Godiva of an incidental neutron reflector (the furnace for heating the sample) causing additional reactivity and a neutron burst above that expected. The neutron reflector may have been jarred by the action of pneumatic cylinders which operate the assembly.

Godiva will be replaced with a bare uranium device designed specifically for prompt burst production. To insure reliability of operation the following features will be incorporated:

1. Rigid mounting of uranium.
2. Uranium will be plated to prevent flaking.
3. Inflexible geometry.
4. Combination gross-mass adjusting rod and auxiliary scram, fixed value reactivity booster for burst generation.
5. Cage to establish minimum spacing of objects to be irradiated.
6. Remotely positionable neutron source.

AIRBORNE IRIDIUM 192 IN LABORATORY

Texas, March 13, 1957.

Nature of accident

Release of radioactive iridium 192 in a laboratory.

Description of operation

The encapsulation of radioisotope sources.

Details of accident

Two employees, one in protective clothing and respirator and one in street clothes, were engaged in opening a sealed aluminum can containing 10 radioactive iridium sources consisting of iridium-aluminum pressed pellets ⅛-inch by ⅛-inch right cylinders. Each pellet consisted of approximately 35 curies of iridium 192. To permit the removal of the plug containing the pellets from the can, the end of the can was cut with a jeweler's lathe in a sealed plexiglas box which, in turn, was in a hot cell consisting of 33-inch thick concrete walls, a shielded window, and an open top. Remote control slave manipulators were used by the operators. This operation was completed in the morning.

The can was allowed to remain in the sealed plexiglas box for a period of time to permit any contamination to settle in the box.

After lunch an employee, again dressed in protective clothing consisting of white pants, shirt, shoes and respirator, opened the sealed box. The second employee who was present that morning was again present in street clothes. The can was removed from the box and placed on a paper mat on the floor of the hot cell, and when the plug was removed from the can it was observed that portions of the first two pellets were in particle form. Some of the particles fell onto the paper mat. During this operation the air monitor device in the laboratory indicated the presence of airborne radioactivity. Subsequently, the employee in street clothes left the laboratory. The employee wearing protective clothing remained in the laboratory. The exact extent or timing of the work he then performed is not known, but it did involve the placing of the eight intact and two partial pellets, together with the particles of iridium 192, in the storage pit at the bottom of the hot cell. Before this employee left the hot cell he placed the storage pit lid in place. He removed his protective clothing, took a shower, and dressed in his street clothes before leaving the premises.

Between the afternoon following the removal of the pellets from the plug and on or about 1 month later, the following events occurred:

(*a*) The eight intact and two partial pellets were encapsulated and placed in a storage well.

(*b*) The air monitor in the laboratory was placed back in service.

(*c*) The jeweler's lathe and paper mat were placed in a waste storage pit.

(*d*) The hot cell was washed with soap, water and sponges, which lowered the radiation level from approximately 2,000 mr per hour to about 20 mr per hour.

(*e*) The jeweler's lathe was removed from storage and sprayed with soft spray. After completion of this procedure the lathe showed a reading of 5,000 mr per hour. It was dismantled, placed in a 5 gallon can of kerosene, and lead bricks were placed around it.

Right after this an employee entered the laboratory, removed a cesium 137 source from the storage well, and loaded it into a projector. At that time the manager noted a high radiation reading outside of the iron doors at the end of the hot cell.

Subsequent to the manager's observation of contamination in the vicinity of the hot cell, he made further inquiries concerning the spread of contamination. During the following week he determined that the laboratory area was contaminated, that employees' street clothes and shoes had been contaminated as a result of the incident and that some radioactive material had been carried into employees' homes and automobiles.

One more entry was made to the laboratory, when the manager entered to procure some equipment. It was then closed down until decontamination work was begun.

Nature of injuries or loss

Radiation exposures received by employees while working in the laboratory area show that neither of the two employees present in the laboratory at the time of the accident received a radiation exposure, during the week the accident occurred, in excess of permissible values established in the AEC "Standards for Protection Against Radiation."

About 4 weeks after the accident occurred, one of the employees received an exposure of 1,720 millirems, which is about twice the

exposure permissible under the regulations for any period of 7 consecutive days. This occurred during the clean up operations in the laboratory.

This one employee's cumulative exposure record for 13 consecutive weeks including the week of the accident and the clean up, was 3,875 millirems.

This exposure exceeds the permissible quarterly exposure, under these conditions, by about 25 percent of that permitted by regulation. There were no other overexposures to employees recorded during that period. Twenty persons, nineteen of them employees or members of their families and one a neighbor of an employee, were medically examined. Except for a minor radiation burn noted on each of the two employees who were present at the time of the accident, medical examination were negative.

EXPOSURE TO PLUTONIUM

Hanford, Wash., April 22, 1957.

Nature of accident

Employee exposed to plutonium nitrate.

Description of operation

A maintenance man was unplugging the dip leg of a tank.

Details of accident

A torn glove in a glove box hood resulted in an employee's thumb and finger being contaminated with plutonium nitrate. The electric drill the employee was using to unplug the dip leg stalled and stopped. When the employee attempted to pull the drill out the chuck rotated in an opposite direction to the spiral bit and caused the hood glove and both surgical gloves he was wearing to twist around the chuck and tear. To prevent contamination spread the hand was wrapped in a wet cloth as it was drawn from the glove box opening. After the hand was wiped the left thumb and index finger were contaminated to a level of 0.15 mc. Decontamination efforts were continued at first aid until the skin was too thin to continue. The hand was coated with plastic at 0.0025 mc and decontamination efforts were discontinued until the following day. At that time the plastic was removed and the level dropped to 0.001 mc or less.

Nature of injuries or loss

Since the accident five samples have been analyzed, all of which have been negative. It can be said that there was no external or internal deposition of plutonium. The employee is working at his regular assigned duties.

DRY BOX EXPLOSION

Rocky Flats, Colo., June 14, 1957.

Nature of accident

Two men injured by an explosion in a dry box.

Description of operation

The men were performing a routine operation inside a sealed dry box.

Details of accident

When a whistling noise was detected during a routine operation, the operators decided to vacate the vicinity. The explosion occurred during this evacuation, which resulted in the shattering of glass and blowing out one of the panels of the box. The individuals concerned were sprayed or struck by flying debris, causing minor abrasions and cuts and considerable plutonium contamination.

Nature of injuries or loss

One employee had a cut on right temple and eyebrow and a minor cut on his lower right cheek. The other employee involved in the accident had a surgical amputation of $\frac{5}{16}$-inch bone, distal phalange, right little finger, to remove the plutonium. Four-tenths of a microgram of plutonium was deposited in an abrasion wound on the face of one man, and about 0.5 micrograms of plutonium in a wound on the second. Losses due to damage to the dry box, equipment, room, and clean up costs were $31,000.

Remarks

Adequate safety enclosures should be utilized and designed to resist the explosive release of the total energies available. Equipment provided for work of this nature should be designed with recognition of and provision for the explosion hazards normally associated with materials of this nature.

BETA BURNS TO HAND

University of California Radiation Laboratory, June 27, 1957.

Nature of accident

An employee received a 1,000 to 2,000 rem dose to his hand.

Description of operation

The employee was working in a glove box with about 85 mc of strontium 90 contained in a centrifuge tube.

Details of accident

During the processing of strontium carbonate in a glove box an employee received beta burns on a part of the hand holding the centrifuge tube as a result of misjudgment of the amount of beta attenuation achieved through the glass wall of the tube and his rubber gloves.

Nature of injuries or loss

The damage consisted of blisters which developed in about 2 weeks. Under the surveillance of the medical group but without necessity of treatment, the condition cleared up and as of the present time there is no evidence of permanent damage. This accident did not constitute a spill or involve contamination.

EXPLOSION IN GLOVE BOX LINE OF PLUTONIUM FACILITY

Los Alamos, N. Mex., August 16, 1957.

Nature of accident

Explosion in plutonium processing hoods.

Description of operation

Manufacture of plutonium metal.

Details of accident

A chemical operator was cleaning rust from lathe collets in one of a series of connected glove box hoods, using a motor-driven (open-case) rotating brush. At the same time, a machinist was coating a lathe and chain hoist with a flammable lubricating and rust-preventive solution in an interconnected glove box. Vapor from the flammable solution which the machinist was using circulated throughout all the hoods, and sparks from the chemical operator's electric rotating brush caused the explosion. (Combustible plutonium dust in some of the boxes may have contributed to the explosion.)

Nature of injuries or loss

The chemical operator received a slight contusion on the head and another employee received a blow on the shoulder. Exposure to men in the room from plutonium-contaminated dust was less than 1 percent of the maximum permissible body burden.

Remarks

A nonflammable solvent will be substituted for general cleaning. Also a study is being made to determine if a rust-preventive solution with a nonflammable vehicle can be found that will meet operational requirements.

METALLIC PLUTONIUM FIRE

Rocky Flats, Colo., September 11, 1957.

Nature of accident

A small amount of metallic plutonium spontaneously ignited and transmitted fire to the plastic structure of the dry box in which it was stored.

Description of operation

Plutonium processing.

Details of accident

At 10:10 p.m., watchmen discovered a fire which appeared to involve plutonium within a dry box, polyethylene parts of the box itself, and rubber gloves (normally used to prevent skin contact during handling of plutonium). Knowing that plutonium was handled and stored in the area, and might be involved in the fire, firefighting was delayed until personnel could put on protective clothing and evaluate the hazards involved. Portable carbon dioxide extinguishers, ranging up to 100-pound units, were emptied on the fire without effect. Although there was considerable uncertainty regarding the criticality hazards involved, if water should be applied, water was finally applied to the fire in form of a spray and this proved effective for control of the fire, with no nuclear event. Spontaneous ignition of plutonium chips in a container stored in the dry box was determined to be the origin of the fire.

The fire had two serious consequences:

(1) It allowed escape and dissemination of considerable plutonium oxide throughout the immediate area in the plant;

(2) It burned through the combustible CWS filter at the dry box permitting flames and some unburned combustible gases to pass through primary exhaust air ductwork to the large main bank of filters which were of a combustible type.

Combating fire in the main filter bank was impeded both by radiological hazards to personnel and by difficulties in selecting methods for extinguishing the fire without simultaneously destroying the integrity of the filters.

On two occasions during the fire, low order explosions were experienced from not fully explained causes, but suspected to be due to ignition of gases generated by plastic heated in the fire. About 13 hours after its inception, the last remnants of the blaze were extinguished, Virtually all of the units in the large filter bank were destroyed.

Nature of injury or loss

No employees were overexposed to radiation. Fire damage and contamination cleanup losses were considerable.

RADIATION EXPOSURE

Oak Ridge, Tenn., October 4, 1957.

Nature of accident

An employee accidentally exposed himself to radiation.

Description of operation

Chemical processing operation.

Details of accident

An employee accidentally received an exposure to radiation when he mistakenly entered a room containing highly radioactive material and received exposure for less than 1 minute to a level of 49 roentgens. The room he entered contained chemical tanks of radioactive residues used in connection with processing irradiated fuel elements.

The individual concerned entered the locked rooms, by mistake, using a key he was permitted to carry, to seek a wrench he thought he had left. It turned out that the wrench was in the next room.

The accident was first discovered when a pencil-type radiation detection instrument was examined at the end of the day's shift and was confirmed when film badge was processed.

Nature of injuries or loss

The exposure received amounted to slightly less than three and a half times the exposure normally permitted in 1 year for workers in atomic energy facilities who are exposed routinely to radiation. The individual apparently suffered no ill effects and continued working, but was transferred to other work.

JANUARY THROUGH DECEMBER 1958

EXPOSURE ACCIDENT

Rocky Flats, Colo., February 4, 1958.

Nature of accident

Employee received ingested radiation.

Description of operation

Changing filters in a prefilter bank.

Details of accident

A boiler-ventilator operator was changing filters. He was engaged in this work for about 1 hour.

Later, a check by health physics personnel indicated he had received some ingested radiation. An examination of the mask used by the employee showed that the filter paper in the mask had been crimped, allowing unfiltered air to come through.

Nature of injuries or loss

The employee received as much as one-half the body burden

HOT BOX FIRE

Freeport, Ill., May 6, 1958.

Nature of accident

Hotbox fire.

Description of operation

Rail shipment of radioactive material.

Details of accident

A journal box fire had occurred on a flatcar in railroad yards. The fire spread to the wooden platform of the car. Railroad employees attempted to extinguish the fire but could not. The local fire department was called and extinguished the fire using CO_2 and a booster (water) line.

Nature of injuries or loss

The fire did not involve the shipment, so there was no radiation problem.

Remarks

Hot box fires are fairly common and can easily spread to the wooden platform of a car, as happened in this case. Exposure to shipments of radioactive materials and to structural members holding shipments in place could be reduced by replacing such platforms with suitable noncombustible material. It could be reduced to a lesser extent by insulating the underside of wooden platforms (over the journal boxes) with suitable noncombustible material to minimize the possibility of a hot box fire spreading to the wooden platform.

TENTH AEC CRITICALITY ACCIDENT

Oak Ridge, Tenn., June 16, 1958.

Nature of accident

A criticality accident occurred in a 55-gallon stainless steel drum at a production facility.

Description of operation

Eight employees were in the vicinity of the drum at the time of the accident. All of them were carrying out routine plant operations and maintenance. One employee, a chemical operator, was participating in the leak testing which inadvertently set off the reaction. He was within 3 to 6 feet of the drum when the incident occurred. The other seven were from 15 to 50 feet away at the time. Two were engaged in

installing ductwork; two electricians were engaged in removing conduit; two others, a welder and a machinist, were located on a mezzanine near the scene of the incident, and the seventh, a chemical operator, was in the process of starting up an evaporator some 50 feet away.

Details of accident

On the afternoon of the incident, eight men were working in a wing of a processing plant. A chemical operator noticed a sudden blue flash and immediately thereafter heard the evacuation alarm sound, indicating existence of excessive radiation hazards. He and the others promptly left the building. All employees evacuated following preestablished emergency procedures. As a precautionary measure, the road to the plant was barricaded and employees reporting on the afternoon shift were delayed from reporting to work.

Specialists, brought in to determine the source of radiation, established the specific location of the incident and defined the radiation field. Road blocks were removed and employees were allowed to enter all work areas, with exception of that portion of the building where the incident occurred.

Immediate efforts were directed toward determining whether any individual had been exposed to excessive radiation, providing medical care, and in decontaminating and cleaning up the affected building wing. By this time, it had been established that a criticality or nuclear excursion had occurred in a 55-gallon stainless steel drum.

A diagram showing the principal equipment involved in the accident is shown. Immediately prior to the accident, tanks (Nos. 2 and 3 in the diagram) were being leak-tested with water. Before this, and unknown to the operator, it is believed, that due to valve leakage and/or operator error, enriched unranium solution had flowed from storage tank No. 1, partially filling tank No. 2.

The balance of the void area in tank No. 2 was filled with water during leak testing. When the operator opened valve A to drain the contents of tank No. 2 into the stainless steel drum, the level of enriched uranium solution in the drum built up to a point permitting initiation of a critical nuclear reaction, accompanied by the "blue glow" in the solution seen by the operator. The enriched uranium solution flowing from tank No. 2 into the drum was followed by water from the same source, which diluted the solution in the drum below the concentration necessary to maintain the critical reaction.

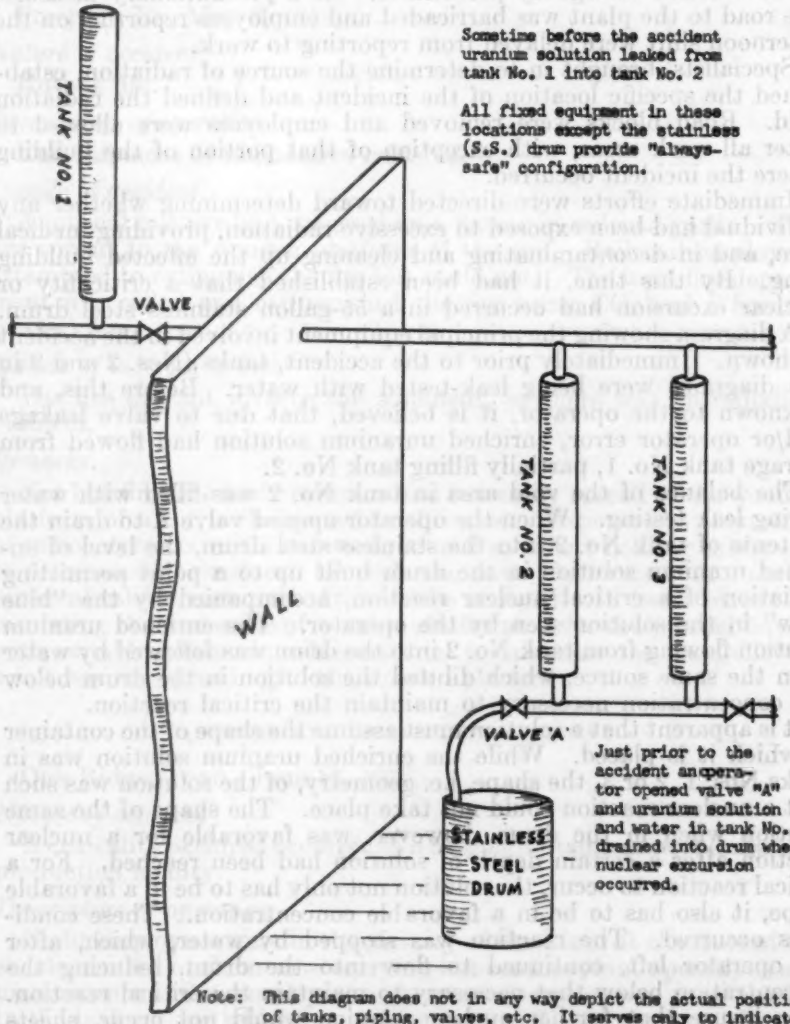
It is apparent that a solution must assume the shape of the container in which it is placed. While the enriched uranium solution was in tanks Nos. 1, 2 or 3, the shape, i.e. geometry, of the solution was such that a nuclear reaction could not take place. The shape of the same solution when in the drum, however, was favorable for a nuclear reaction after a certain depth of solution had been reached. For a critical reaction to occur, the solution not only has to be in a favorable shape, it also has to be in a favorable concentration. These conditions occurred. The reaction was stopped by water, which, after the operator left, continued to flow into the drum, reducing the concentration below that necessary to maintain the critical reaction.

To insure that further nuclear reaction would not occur, sheets of cadmium, a neutron-absorbing material, were inserted into the 55-gallon drum. Samples of the material in the drum were taken for

analysis and later the contents of the drum were transferred to "always-safe" containers and removed to a shielded location. There was no explosion, nor would one be expected under the circumstances. However, there was emission of radiation from the nuclear excursion which is believed to have occurred in a pulsing manner with periodic emissions of radiation for a duration of not exceeding 4 minutes.

Nature of injuries or loss

Since the determination of radiation exposure from a reaction of this type is complicated under any circumstances, special methods were used to determine the neutron and gamma exposure of the individuals nearby.


Sometime before the accident uranium solution leaked from tank No. 1 into tank No. 2
All fixed equipment in these locations except the stainless (S.S.) drum provide "always-safe" configuration.
TANK NO. 1
VALVE
TANK NO. 2
TANK NO. 3
WALL
VALVE 'A'
Just prior to the accident an operator opened valve "A" and uranium solution and water in tank No. 2 drained into drum where nuclear excursion occurred.
STAINLESS STEEL DRUM
Note: This diagram does not in any way depict the actual positions of tanks, piping, valves, etc. It serves only to indicate relative schematic arrangement of vessels and equipment.

These methods included readings from indium foil which is incorporated in all security badges; determining the radioactivity of sodium 24 in the bodies of those exposed through whole body and blood counting; and by measurements obtained through a mockup of the accident.

Through use of these methods, it was estimated that the eight men received the following radiation exposures: 461 rem, 428 rem, 413 rem, 341 rem, 298 rem, 86 rem, 86 rem, and 29 rem.

Property contamination

Contamination of the area was slight. Decontamination costs were under $1,000.

NOTE.—A complete technical report of this incident is available from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C. Price $2.75.

X-RAY TECHNICIAN EXPOSED

Middletown, Conn., June 16, 1958.

Nature of accident

Exposed to X-ray radiation.

Description of operation

Taking X-ray of a metal tube in an X-ray room.

Details of accident

X-ray technician had completed the taking of an X-ray of a metal tube. The X-ray machine was operated at 100 kv. and 10 ma. for a period of 1 minute. Employee stated that the timer returned to zero and the red warning light on the panel went out. Therefore, he entered the X-ray room to change his setup in preparation for another picture. Unknown to the X-ray technician, he was being exposed to X-ray radiation because of a malfunctioning panel.

Nature of injuries or loss

Employee film badge indicated he was exposed to a radiation level of 885 mr.

RADIUM-BERYLLIUM SHIPMENT VEHICLE ACCIDENT

Grand Junction, Colo., June 20, 1958.

Nature of accident

A truck carrying a radioactive source went out of control down an embankment into the Colorado River.

Description of operation

Transporting radioactive source by truck.

Details of accident

The truck carrying the source went out of control, plunged into the river, and submerged in about 30 feet of water.

Skin divers entered the river, located the truck, and secured a cable to the front tow bar to enable a wrecker to draw the truck to the bank of the river. A line was secured to the frame of the truck from a large crane, and it was in position to raise the truck from the water. This

was done, and the truck was suspended vertically on the road for inspection.

Nature of injuries or loss

Damage to the turck was largely confined to the cab and the top portion of the van. The source was located in the lower right side of the van, shielded in a spherical container inside a compartment of the van. Neither the compartment nor the source container were damaged. No exposure of consequence was received by the public or salvage personnel.

FIRE INVOLVING RADIOACTIVE MATERIAL

Attleboro, Mass., June 23, 1958.

Nature of accident

Fire involving 6 pounds of slightly enriched uranium.

Description of operation

Degreasing uranium in a portable electric vapor degreaser.

Details of accident

A fire occurred when slightly enriched uranium scrap had just been degreased with perchoroethylene.

The local fire department was called, but the fire was extinguished without their assistance.

Smoke within the building was cleared by means of an exhaust ventilation system which includes noncombustible prefilters and absolute filters.

Nature of injuries or loss

No personnel were overexposed or injured as a result of the fire, and no material was lost.

TRITIUM GAS RELEASE

Los Alamos, N. Mex., July 25, 1958.

Nature of accident

An increase in activity in the exhaust air from the hood indicated radioactive gas was released to the atmosphere.

Description of operation

Laboratory experiment.

Details of accident

A small amount of tritium gas escaped from the laboratory gas handling system into the atmosphere via the exhaust system. The probable loss was caused by a failure of a ring which seals around a movable piston in one of the pumping cylinders.

The area was evacuated and the site temporarily closed, as a precautionary measure, following the leakage.

Nature of injuries or loss

The wind direction at the time of evacuation was ideal in that no personnel were located immediately downwind, and dissolution and dispersal were immediate. The concentration in the room did not increase above background.

Following the accident, urine assays of samples submitted by site personnel were all below the permissible level.

POLONIUM ACCIDENT

Miamisburg, Ohio, December 4, 1958.

Nature of accident

Employee inhaled polonium 210.

Description of operation

Handling and counting of a polonium alpha source.

Details of the accident

The exposure occurred during the handling and counting of a polonium 210 source. The source was odd sized, and it was necessary to count it in an unorthodox manner.

Nature of injuries or loss

The employee received an estimated body burden of 3.5 times the maximum continuous body burden.

Remarks

Operating groups have been instructed that, in the future, respiratory protection must be worn by personnel during any counting operations which cannot be done in the normal manner.

FATAL INJURY ACCOMPANIES 11TH AEC CRITICALITY ACCIDENT

Los Alamos, N. Mex., December 30, 1958

Nature of accident

Criticality accident occurred in a 225-gallon stainless steel tank.

Description of operation

Plutonium recovery operation.

Details of accident

After placing the emulsion in the tank, the operator was believed to have added a dilute plutonium solution from a second tank. Solids containing plutonium were probably washed from the bottom of the second tank with nitric acid and the resultant mixture of nitric acid and plutonium-bearing solids added to the tank containing the emulsion. Shortly after starting the stirrer motor to initiate an expected mild nonnuclear reaction between the emulsion and the acid, the operator observed a "blue flash," which was also observed by a second employee in an adjoining room.

The operator then ran out of the building and told a second employee: "I am burning up." Perhaps because of an incorrect belief that the "burning" feeling had resulted from acid exposure, the employee was led to a shower.

Nature of injuries or loss

The employee died 35 hours later from the effects of a radiation exposure tentatively estimated at 12,000 rem (plus or minus 50 percent).

Two employees (other than the operator) received radiation exposures ranging up to 118 rem. These employees were not seriously injured. Property damage was reported as negligible.

NOTE.—When the investigation is completed, the report will be available from the Office of Technical Services, U.S. Department of Commerce, Washington 25, D.C.

○